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FUTURE Digital Edition

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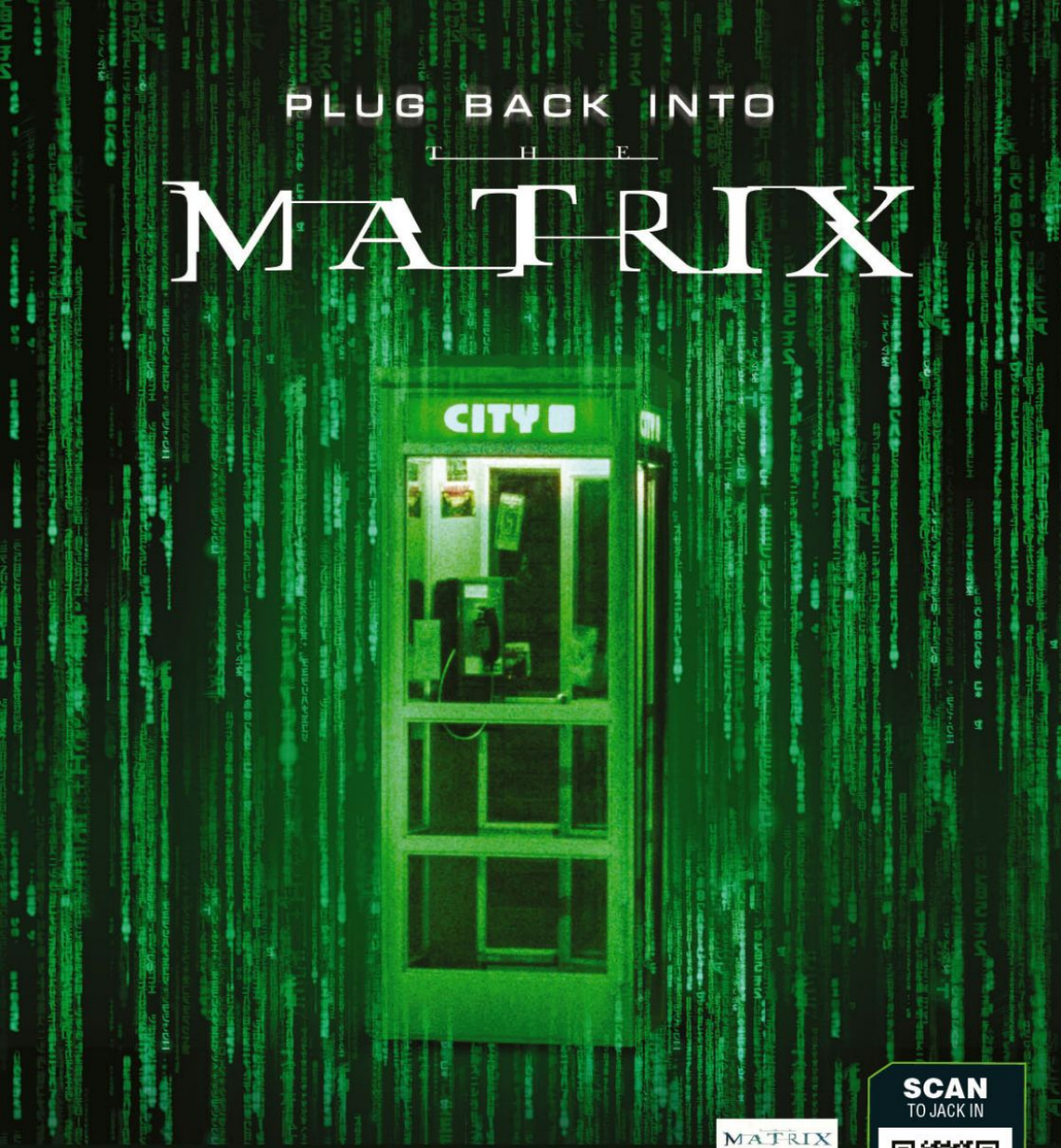
THE

MATRIX



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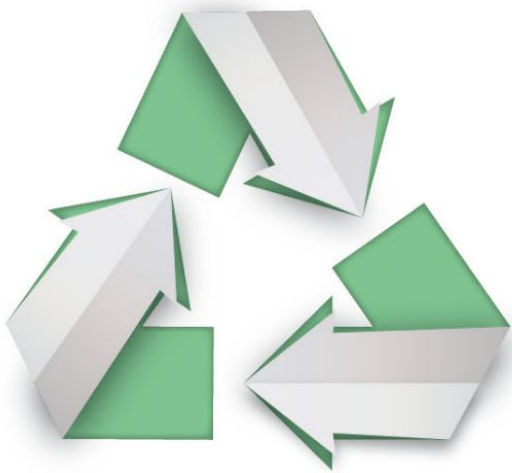

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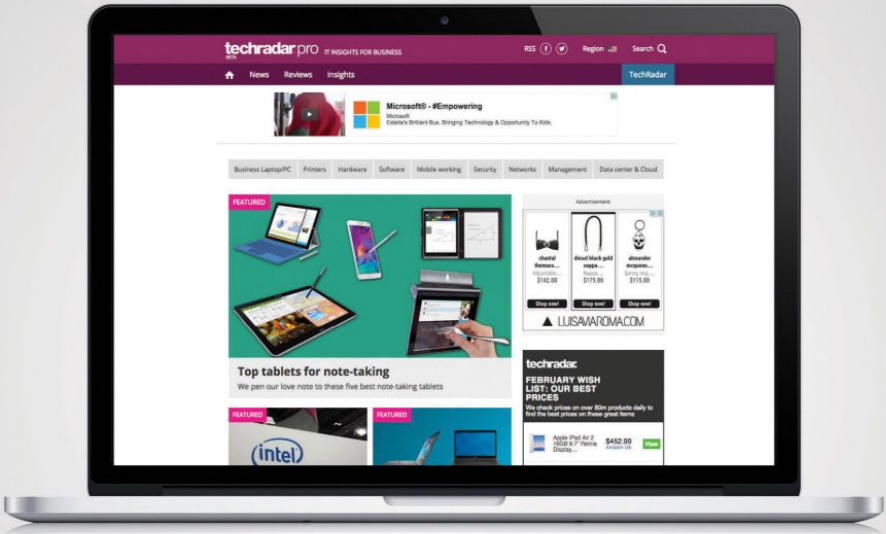

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Zak Storey

BACKING UP THE FUTURE

I AM FASCINATED WITH AI. It's one of those things that is simultaneously terrifying and exceedingly exciting from both a technological and philosophical point of view. We've all seen *Terminator*, I'm sure, and the idea of an advanced, hyper-intelligent, self-learning, self-replicating machine race certainly does have its own horrifying implications for humanity. But on the flip side, the advancements and jumps AI could potentially produce in the worlds of medicine, technology, astrophysics, and everything else in between mean it's too enticing not to embark upon.

And, let's face it, these are still ultimately going to be machines that are confined by rules, physics, and properties that limit their capability. Nonetheless, AI is also something of a buzz-acronym. Similar to nuclear fusion, it's one of those things that's always been "just 10 years away," so to get a better understanding of where the AI industry and its development are right now, this issue we sent Jeremy Laird out to get a better understanding of the whole kit and caboodle for us, then write it all down in eight copy-rich pages.

AI revolutions aside, when the technological apocalypse does finally arrive, having a decent backup of all of our most important files and documents is going to be paramount. To that end, we got Nick Peers in to divulge all his knowledge and secrets about backing up your own digital lives, covering everything from Macrium Reflect, to local NAS drives, Windows File History, online solutions, and more.

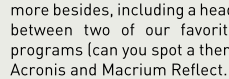
On top of that, we've got two more epic features: One is a fancy ITX build squeezed inside the wonderfully weird Lian Li Tu150 case (it has a handle on the top), and the other being Ian's look at the best games of the last decade that everyone should play, at least once, during their lifetime.

For tutorials this month we're moving away from Photoshop and taking a look at another of Adobe's excellent artistic tools: Illustrator. Meanwhile, Ian has a fantastic guide to getting your PC ready for Windows 11 (more on that next issue), Alex explains how to turn a Raspberry Pi into a NAS, and we get you up and running with RetroPie for all your old-school gaming needs.

To round all that off, we're finally wrapping up our GPU launch coverage, with the RTX 3070 Ti, plus we have a pair of laptops in the form of the MSI GL66 and the Alienware M15, and a ton more besides, including a head-to-head between two of our favorite backup programs (can you spot a theme here?), Acronis and Macrium Reflect.

With a whole heap of columns, builds, letters, reviews, and more, I hope you enjoy the latest issue of *Maximum PC*. It's been a pleasure to put together, and there's even more to come next issue.

Stay safe out there, folks, and until next time!



Zak is Maximum PC*'s editor-in-chief and long-time staff member. He's been building PCs since he was 10, and is more than capable of butting heads with the biggest names in tech.*

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THE NEWS

Can You Run Win 11?

Windows 11 system requirements cause confusion

AS YOU DON'T live under a rock, you'll know we are to be graced with Windows 11 shortly. And as this is a Microsoft launch, you know that somewhere something didn't go quite to plan. The shiny new OS may be just the job, but the hardware specifications you need to run it haven't exactly been easy to follow, causing headaches and anger as it appeared that a lot of relatively new rigs weren't going to make the cut.

The first thing that caught people's eye was the requirement for TPM 2.0. What is TPM? It's a Trusted Platform Module, a chip (or integrated into the chipset or firmware) used to authenticate hardware devices. It includes a unique security key, and can generate encryption keys among other things. The Department of Defense won't buy anything without one. On home PCs, it's used by Office 365 and Defender, among others. TPM 1.2 has been around since 2011, a standard feature of OEM systems since 2016, and built into most motherboards since 2015, although it might not be enabled by default.

Not too bad, but the specs for TPM 2.0 were published in 2019. Just two years ago. It transpires that TPM 2.0 was Microsoft's "soft floor," and it will fine run on TPM 1.2. It would have been useful to know that straight away. We are at least spared having to source plug-in TPM modules (at $20–$50 a pop). There are some good reasons for wanting TPM 2.0, but Microsoft didn't bother to tell anybody. If you built your rig yourself out of older or specialist parts, you may have missed this little chap off the list of components. Be warned: There's a number of different pin-outs. Win 11 also needs Secure Boot enabled, which means you need UEFI, Unified Extensible Firmware Interface, which has been about since 2007.

OK, how about processor requirements? The official Win 11 requirements just say a 1GHz processor with two cores and 64-bit compatible. Not too onerous. Elsewhere we had a different story—apparently you need an eighth-gen Intel CPU, so no Coffee Lake chips. AMD lost the first generation of Threadripper chips, along with the Ryzen 1700X, 1800X, 2200G, and 2400G. To clear things up, Microsoft produced a document that specifies more exactly which chip will work, and if your chip isn't on the list, it won't run. Basically, if it was made before 2017, you're out of luck, and many newer chips aren't on the list. There are a lot of high-power seventh-gen rigs out there, and we still await a concise answer as to why they aren't suitable. A fifth-gen chip lacks Software Guard, Memory Protection Extensions, and Trusted Execution Technology; given the effort to improve PC security, we have a solid reason for their exclusion. This appears to be a line in the sand, rather than a practical cut-off. There are rumors that this line might move, too.

People have tried to get around the requirements by editing the registry. You still need that TPM module, but otherwise it is possible to get what shouldn't run Win 11 into the Win 11 Insider Program. Whether this will work on the finished version remains to be seen. Others have been experimenting using ISO files and even older gear, including third-gen Intel silicon.

Microsoft released a tool, PC Health Check, which told you if your system is suitable for Win 11. It wasn't terribly forgiving or informative. It failed many systems that probably could run Win 11, and didn't tell you why. It also passed a number of seventh-gen CPUs as fit for purpose. What gives? After some fuss, the utility went offline; we can expect a more comprehensive and helpful version before the full Windows 11 launch.

Win 11 will be a free update for Win 10 users, so we'll see a lot of machines trying to update at once. Microsoft needs this mass installation to go smoothly, and it hasn't got off to a good start. Perhaps we are being harsh. To think you can't run Win 11 only to discover you can is probably better than the other way around. But publishing a confusing and demanding list of requirements has led to many thinking they need a new PC (and now is not a good time to buy one). You probably don't if you have anything reasonably modern.

The requirements appear arbitrary in places, and more like a wish list than a "hard floor." Some are there for good reason; the Secure Boot and TPM requirements will improve security—Microsoft is competing with Apple, which has always been much better. Microsoft wants to get TPM and Secure Boot on every box, even if you don't need them. The CPU specs aren't as easy to defend. Don't buy a new PC for Windows 11 just yet. **–CL**

> People have tried to get around the requirements by editing the registry.

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GPU PRICES FALLING

MINING BAN STABILIZES MARKET

AT LAST WE HAVE SIGNS that the ridiculous prices charged for graphics cards have peaked. There is still a healthy premium, though, and supplies remain tight. The finger of blame is generally pointed at cryptocurrency miners. In the first quarter of the year, they consumed around 700,000 mid- and high-range graphics cards—about a quarter of the entire market. Thankfully, demand is dropping, thanks in a large part to the Chinese government, which has started restricting the mining and trading of cryptocurrencies, and is even considering an outright ban. China currently mines over 70 percent of the world's coins, often in remote areas such as Inner Mongolia and Xinjiang, where electricity is cheap. It is also largely from coal, which isn't popular. Market analysts predict prices will return to near normal by next year. **–CL**

WINDOWS' PRINT NIGHTMARE

Patch required after bug details appear online

IN MAY, RESEARCHERS uncovered a vulnerability in Windows that could enable hackers to access people's printers. Unfortunately, they put the proof of concept online, so a potential threat became a real one. Apparently, they assumed that Microsoft had fixed the problem. Two bugs had been merged into one Microsoft security indicator, but only one had been fixed. The flaw enables hackers to remotely execute code with system level access. The Cybersecurity and Infrastructure Security Agency issued an emergency directive to federal agencies to disable the Windows Print Spooler or risk the compromise of the "entire identity infrastructure of a targeted organization." Cue an emergency patch from Microsoft. The fix did cause a few printers to stop working, but it's hardly unheard of for a patch to break something else. A new patch followed quickly. We think the lesson here is: Don't assume Microsoft has fixed anything. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

EXPENSIVE PLUMBER
A mint copy of *Super Mario 64* sold for $1.5m at auction—12 million of these were made originally.

HOLOGRAPHIC MONITOR
Looking Glass Factory has launched its Gen 2 3D monitors, no glasses needed. A 32-inch 8K model is $17,500. Pricey but cool.

BILLIONAIRE SPACE RACE
Richard Branson has been to space in his own spaceship. Bezos and Musk will no doubt soon join this rather exclusive club.

TRAGEDIES

COMMERCIALS IN GAMES
EA has signed a deal to integrate ads in games. If you watch them you earn an in-game perk, but it increases load times. Boo.

NEWEGG'S OEM IDEA
If you want to buy a "hot item" it's only available in a complete system with a $99 fee on top, and no additional warranties.

CHINA'S GAMING CURFEW
To ensure under-18s don't play all night, Tencent has added a facial recognition system to games.

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Kaseya

WORLDWIDE RANSOMWARE ATTACK

$70m demanded after major IT supplier hit

A RUSSIAN-BASED group of hackers known as REvil has broken into Kaseya, a Miami-based company that provides IT services, including VSA, a remote monitoring tool for networks. Modifications were made to VSA, which was unwittingly used by the victims, enabling the hackers to start encrypting files. As soon as the breach was noticed, Kaseya recommended that its customers shut down VSA, and it took all its data centers offline. A fix was in place three days later, but damage had been done. Part of VSA's job is the automated distribution of software across networks, which makes it an ideal target for these attacks. It's unclear how many companies have been compromised; Kaseya claims it's 50. However, these companies have their own customers, and it's estimated that 1,000 to 2,000 business have been compromised. Among them was a Swedish grocery chain that had to close 800 stores as its tills stopped working. Fortunately, damage in the US appears to be light, but that is down to luck. This looks like the biggest ransomware attack yet.

A post on a blog frequented by the gang demanded $70m to unlock all the data in one go. This a prolific and organized group of hackers that carries out attacks purely for profit. Last month it managed to extort $11m from a Brazilian meatpacking company after it paralyzed its North American and Australian operations.

US intelligence agencies are on the case, but tracking down shadowy groups hiding abroad is difficult. However, when attacks get this big, they start to worry governments everywhere. There have been hints from authorities here that action against servers used to launch these attacks is under consideration. Interestingly, REvil's payment website, and blogs used by REvil, suddenly went offline two weeks after the attack, leading to speculation about who, and how, pressure was brought to bear. **–CL**

WINDOWS IN THE CLOUD

New subscription service launches

MICROSOFT HAS LAUNCHED a new Cloud PC service: Windows 365. For a monthly fee, you'll be able to access a virtual copy of Windows sitting on an Azure server. This is apparently a "new era of hybrid personal computing." You'll be able to run your Windows system on any suitable device wherever you are (including Mac, Linux, and Android systems, and via a browser), ideal for remote working. You can jump straight into a Windows session, with everything as you left it. All you need is a reasonable Internet connection. The thin client model means you won't need a beefy machine to run intensive applications.

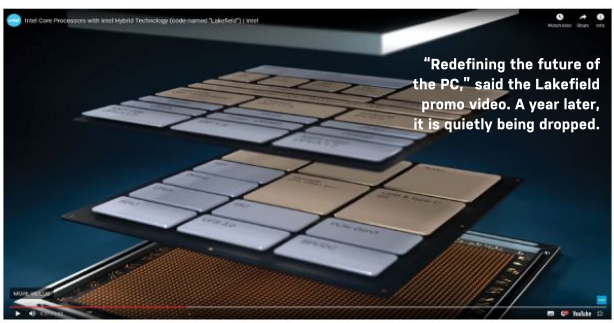
There are multiple levels of service, with differing amounts of processing power, memory, and storage. For light office work, you can have a 2GB single-CPU system with 64GB of storage. At the high end, there's an eight-CPU virtual machine, with 32GB of RAM and up to 512GB of storage, aimed at content creators and software developers. Support, if you use a Windows rig, includes multiple monitors, printers, scanners, cameras, and local storage. On other systems, support is more limited, although it will improve.

Windows may be on millions of PCs, but Microsoft doesn't make much from selling it. OEM installations are a few bucks each, and Win 11 will be a free upgrade. Making money out of software the old-school way is difficult. Top PC games aside, it's easy to get a full range of apps for next to nothing given the amount of high-quality freeware around. The answer is the subscription model, as seen with Microsoft/Office 365. There's a generation of people happy to rent rather than own. The idea is that Windows will transform into a service, rather than an OS you buy once, then Microsoft can tap your wallet every month. **–CL**

Intel Kills Lakefield

INTEL ISSUES PRODUCT CHANGE notifications regularly, listing chips due to be discontinued. Its last list of 24 included some surprisingly recent silicon, including tenth-generation Comet Lake and Ice Lake chips, as well as 11th-gen Lakefield chips, which will all disappear by spring 2022. Losing Ice Lake so early has to be disappointing for Intel; it's relatively new, but never performed that well. However, the real surprise is the dumping of Lakefield—it was only launched in June 2020. As Intel prosaically put it, "Market demand for the products listed has shifted to other Intel products." Translation: People didn't want to buy them. It added that "they demonstrated the potential of hybrid x86 CPU and new packaging technology."

Lakefield is Intel's only hybrid design that mixes small and big CPU cores, in this case Atom Tremont and Sunny Cove, using Foveros, Intel's die-stacking system. It only appeared inside a couple of high-end OEM systems, a Samsung Galaxy and a Lenovo ThinkPad. But high-speed switching between the cores was less than ideal, and the systems were outperformed by cheaper machines using simpler "big" processors. Microsoft was due to build a Surface Neo using Lakefield, but that ain't going to happen. Hybrid designs, as proved by Apple, can be superb, but Intel's first stab at the concept will have to be chalked up as a learning experience. The next step of the hybrid, Alder Lake, due later this year, will carry Gracemont and Golden Cove cores coupled to an Xe GPU. The second time is the charm, right? **–CL**



Ring Gets Encryption

Ring has added end-to-end encryption to its smart doorbells. The Electronic Frontier Foundation asked Amazon to implement this last year after concern over the misuse of people's videos, which are stored on Amazon's servers. Until now, Amazon has been free to look at your videos, and a few employees have been fired for unauthorized access. The police can also access footage without your consent or knowledge. Some complain that the new encryption makes the use of footage by law enforcement more difficult; others are happy knowing that random Amazon employees can't watch them fumbling with their keys after a night out. The encryption needs to be actively enabled. **–CL**

WD Drives Delete Everything

A vulnerability in the firmware on Western Digital's My Book Live external HDDs lead to a number of owners waking up on June 23rd to find their drives had been wiped. WD promptly recommended disconnecting the drives from the Internet. There had been a simultaneous world-wide destructive attack by parties unknown. Two vulnerabilities were exploited. One, a known bug discovered in 2018, which enabled unauthorized remote access. More serious was the discovery that code to password-protect the factory reset had been "commented out." Oops. WD is offering free data-recovery services, as well a trade-in program. An apposite reminder to make backups. **–CL**

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Jarred Walton

TECH TALK

China's Crypto Crackdown

IT TOOK LONGER THAN MANY OF US EXPECTED, but the beginning of the end for the latest surge in cryptocurrency prices seems to have finally arrived. Predicting this stuff is about as accurate as predicting the weather 28 days in advance, and who knows? By the time you read this, maybe something else will have happened and prices will be heading back up. But realistically, China's crackdown on mining and cryptocurrency use in general looks to have radically altered the cryptolandscape. Sorry, no more made-up cryptowords, I promise.

This isn't the first time China has taken a negative stance toward bitcoin and its ilk, but in the most recent surge, things apparently got a bit out of hand. Now, the Chinese government is taking a dual-pronged approach to attacking crypto. First, China has tightened its restrictions on banking and payment companies dealing with cryptocurrencies. While the government already limited what banks could do with crypto since 2013, the latest directions from the People's Bank of China, as an example, state that institutions must not accept virtual currencies in any form or provide the ability to exchange virtual currencies for the Chinese yuan or other foreign currencies. There are also restrictions on storing crypto for people looking to invest, and 2017's ban on ICOs (initial coin offerings) remains in effect.

The new restrictions took effect back in May and had an adverse effect on bitcoin prices, at least for a while. But cryptocurrencies can be resilient and unpredictable beasts, and some thought they might recover. Then China dropped the mining banhammer. It started with Inner Mongolia banning mining in March, then spread to Qinghai, Xinjiang, Yunnan, and Sichuan. These were attractive locations for mining operations, thanks to their cheap electricity costs, not to mention apparently ready access to supplies of mining hardware—it's no surprise that many of the farms appear to use large numbers of graphics cards of the same model.

> Inner Mongolia established a hotline for citizens to report on suspected mining operations.

The ban wasn't just against any future mining projects. Mining groups were apparently instructed to shut down within days—authorities in Sichuan reportedly told miners on June 18 that they had until June 20 to halt. And in a case of Big Brother watching you, Inner Mongolia established a hotline for citizens to report on suspected mining operations. The message is clear: China wants crypto miners to leave.

It's estimated that around 65 percent of all power used by the bitcoin network was in China in 2020. Perhaps more telling, with the government's crackdown on crypto mining, the global network hashrate of bitcoin plummeted from a high of 180.6EH/s (exahash per second) on May 13 to a low of around 85EH/s on July 2. Ethereum wasn't hit quite as hard, dropping from a high of 644TH/s on May 20 to a low of 478TH/s by late June.

It's not just hashrates declining, though. Large quantities of used GPUs are being sold in China, in lots of 100 or more. We're not suggesting people buy used GPUs that might have been mining for years, but one report showed lots of 200 RTX 3060 cards being sold at an average price of $293 each, and lots of 100 RTX 3070 cards at $400 each. There are also reports that graphics card prices in China have dropped by as much as 45 percent.

Which, as far as I'm concerned, is great news. Prices in the US haven't dropped quite that much, but the price of cards sold on eBay fell around 15 percent in the past month. That will hopefully mean reasonably affordable graphics cards will be available to gamers before the end of the year.

The demand from crypto miners may be drying up, and supply appears to be improving, but the lingering effects of the pandemic and worldwide shortages on various chips are still a problem. Cars, smart appliances, computer parts, gaming consoles, TVs, and more have all been impacted by the pandemic, and some analysts predict we won't fully recover until 2023 now. But we're heading in the right direction at least. Or are we? Talen Energy just announced plans to build a 300MW nuclear reactor in Pennsylvania, for cryptomining purposes. *Sigh.*

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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TRADE CHAT

Windows 11: We'll Just Have to Live With It

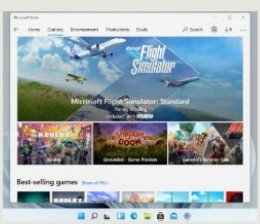
HAVING SPENT SOME TIME running tests (and watching YouTube) in *Maximum PC's* underground lab, we have come to the following conclusions about Windows 11: It is from Microsoft. It is an operating system. And we're all going to have to get used to it, because it's the future.

Windows 11 is a good-looking OS on the surface (also on the Surface, if you've got the right model) with its excellent new desktop background images and, yes, even the rounded corners on its windows. There's loads to like about it, such as the revamped Microsoft Store that seems to run at twice the speed of the Windows 10 version, even in a virtual machine, or the Widgets that slide effortlessly from the left of the screen, a much more elegant solution than a weather report embedded on the taskbar.

But Windows 10 was supposed to be the end. Windows-as-a-service, updated for free, new tech patched in, and old features removed. Such as Live Tiles, which have been removed in 11 to make way for the new technology of static icons. Things like the centralized Start menu are going to take a little while to get used to (of course, there's a few software workarounds for that), but I'm sure we'll get there, just as we learned to accept the Start screen in Windows 8. Oh.

That new Start menu, though, is an awful lot like the one in Windows 10 X, an OS meant for the canned Surface Neo device, which was to run on an Intel Lakefield CPU. Guess what? Intel just end-of-lifed Lakefield, with its successor, Alder Lake, due to launch later this year. The future, for Intel at least, is hybrid CPUs, with one (or more) powerful cores surrounded by low-power cores and a GPU. Apple has taken the same approach with its M1, and it's been common in smartphone processors for years.

> We'll get there, just as we learned to accept the Start screen in Windows 8. Oh.



Windows 11 has certain elegance that Windows 10 never had, and it's a winner in our eyes.

Then there's Microsoft's new fixation on hardware security, restricting the new OS to PCs that hit its spec targets, and being a bit vague about what they are (Zen 2 chips, for example, are mentioned as the oldest AMD architecture supported, but Zen+ model numbers are on the list of compatible chips). For the price of entry, you get a few bonuses immediately—Auto HDR in games, and Direct Storage (where the GPU can talk to the RAM directly instead of having to ask the CPU to take a message), which is an Xbox feature but might benefit non-gamers, too.

So why is it Windows 11, and not a new version of Windows 10? The installation screens we've seen sure do look like the Windows 10 ones. We can only guess that Microsoft needs a New Thing so people will upgrade, so it's drawing a line. The day will come when an app will be Windows 11 only. If it's TikTok, maybe no one will mind, but if it's Office, many thousands of people will be forced to buy new PCs. Then Win 10 will stop getting security patches, forcing the hangers-on to change, too.

Apple does this all the time, but controls its hardware and isn't averse to changing the entire architecture on which it runs. Windows on ARM is going to be a pretty major force in the future, though we're not there yet, and it's possible that this has something to do with the sudden appearance of Windows 11, a shared code-base between X86 and ARM64 that MS suits decided was different enough that it needed a new version number. Note the newfound ability to run Android (ARM) apps on X86.

Windows 11 isn't anything to be afraid of. TPM 2.0 will inevitably become a part of motherboards, Processors will support the virtualization-based security MS is so hot for right now, and it will all happen again with Windows 12. Even if we're told it won't.

Ian Evenden's first PC was a 286 with 640kb of memory. And who could need more than that?

© MICROSOFT

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

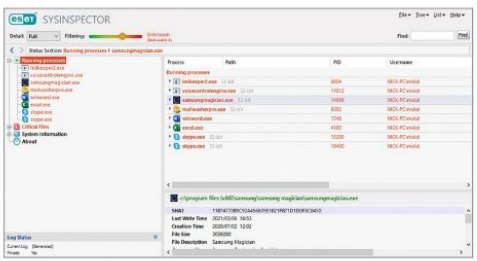
> Malware Infections
> Sleep Problems
> Windows 7 issues

Malware Begone!

I hope the Doctor is in, as I have a very frustrating problem with some adware/malware. My pastor has an older PC running Win 10. It has the free versions of AVG and Malwarebytes installed, along with Windows Defender. A year or so ago, she started getting ads for Staples.com popping up, taking over the Chrome browser. We noticed that while she was working on a document, the Run command prompt would pop up in the lower-left of the screen and she would be taken to Staples.com. I checked the Run command history and found several variations of Staples.com in the list. Some were misspelled. I ran deep scans with AVG and Malwarebytes but found nothing. I erased the Run history, cleared the cache, ran CCleaner, and hoped for the best. Three days later, it happened again, and she was unable to use the computer, as it just kept running the Run command by itself. I scanned her USB drives and a desktop drive that is connected, with nothing found.

Finally, after trying a search for anything with "staple" on the entire computer and finding nothing of note, I did a complete reinstall of Windows 10 without saving any old files. After reinstalling all her software, the machine worked great again. Until recently. The Staples Run command has reappeared. Clearly, something is infected, but scans don't find anything. Can you offer any suggestions as to how to locate the culprit file on USB connected drives?

–Gerry Exstein



ESET SysInspector enables you to see what's running on your PC.

THE DOCTOR RESPONDS: This bears all the hallmarks of a typical virus infection—it might be some random script on your pastor's computer, or it may indicate someone has given themselves remote access to the PC and is manipulating it externally. Either way, you need to close that security hole. The Doc recommends a complete wipe clean and reinstall using Windows installation media, making sure you format the Windows drive before reinstalling Windows on to it.

Once done, up your pastor's security—free software is all well and good, but it's clearly not protecting you here. Choose a comprehensive security suite—such as Bitdefender Total Security—that includes additional protection. In the case of Bitdefender, it contains multiple technologies that actively look for suspicious behavior; in some ways, it's over-protective, but in this case that's preferable to being subject to another attack. In addition, its firewall is two-way, which means it monitors outgoing connections from the PC as well as incoming ones, so if someone has implanted a remote-control tool on your PC, Bitdefender should spot it.

Also make sure security is tightened in other areas. First, physical security. Does anyone else have access to the PC? If it's being shared, your pastor should lock off her own account with a password—which should be changed in case it's been shared with others—then set up guest access or standard (non-administrator) accounts for other users. Also, make sure any shared folders are password-protected, so only trusted contacts have access, and check that no remote-control software has been installed, and that Remote Desktop—not applicable if she's running Windows 10 Home Edition—is disabled. To do this, type "remote access" into the Search box and click "Allow remote connections to this computer"—ensure "Don't allow remote connections to this computer" is selected.

If the problem comes back, use a free tool called

© ESET

↘ submit your questions to: doctor@maximumpc.com

ESET SysInspector (www.eset.com/int/support/sysinspector/) to log all running processes and services—it'll flag any potentially suspicious ones (along with suspicious network connections), which will hopefully provide tell-tale traces of where this infection originated. Feel free to email it back to the Doc and he'll examine it further.

Sleep Reboots

My Dell Inspiron 15 7000 two-in-one laptop sometimes reboots after opening the lid. Control Panel is set to put the computer to sleep when the lid is closed. There's no specific time delay—it might do it after just a few minutes of having closed the lid or after a couple of days. Event Viewer simply says that the shutdown was unexpected. When I close the lid, I usually only have Chrome running with a few extensions. How do I diagnose what's causing the reboots? **–Doug Ochsner**

THE DOCTOR RESPONDS:

First, make sure your BIOS and drivers are all up to date. If the problem persists, try resetting the BIOS to its defaults. Still no luck? Verify that hybrid sleep has been disabled (it should be by default on laptops): Go to "Start → Settings → System → Power & sleep" and click "Additional power settings." Click "Change plan settings" next to the current plan, followed by "Change advanced power settings." Expand "Sleep → Allow hybrid sleep" and change the setting to "Off." Click "OK." If you ever put your laptop to sleep in battery mode, repeat for that power plan, too.

If this doesn't work, try putting the laptop to sleep manually via the "Start" button—if it randomly restarts from here, it's worth running a diagnostic to see what's waking it up (and then subsequently causing it to crash). Right-click the "Start" button and choose "Command Prompt (Admin)." Type the following to generate a power efficiency diagnostics report and save it in your Downloads folder:

```
$ cd %homepath%/Downloads
$ powercfg /energy
```

Wait around 60 seconds for the report to be generated, then open the Downloads folder and double-click the energy-report.html file to view it in your browser. Don't be alarmed at the number of red errors and yellow warnings—many represent normal behavior (such as your drive imaging tool refusing to allow your PC to sleep while it's running). However, they may also reveal potential causes for the reboot—could the reboot be caused by a background app trying to run, for example? If so, check the web for possible causes—is it a known problem with that app, in which case there might be a patch, or failing that, try disabling whatever part of the app is waking your PC, or try uninstalling it to see if that resolves the problem.

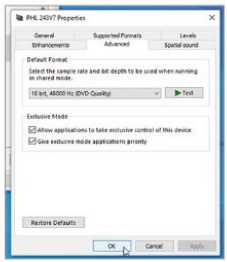
One final thing: Make sure you run a full disk check of drive C. All those reboots may be leading to file corruption issues, in which case a simple chkdsk should fix it—set this up via the same administrator command prompt as earlier:

```
$ chkdsk c: /f /r /x
```

You'll be prompted to schedule disk check for the next reboot, so press Y, then restart your PC, and monitor the check to see whether any errors are found (and fixed). If they are, you may find that the sleep feature now works correctly, too.

App Sound Issues

I'm running Windows 7 Pro—fully updated—and have a long-standing issue. I get no sound in any apps like VLC (fully updated), as well as all other video player software. But I can get sound using "Open with" and any browser, no problem. All sound works in all videos in all browsers;



Check Windows sound settings if you have audio problems.

that's been my workaround. Sound also works for videos in iTunes.

I have tried reinstalling the sound driver (Dell XPS 3770) and uninstalling/reinstalling. When I try to mess with audio settings in VLC, VLC crashes. No sound setting adjustment works at all in other players. Seems like a registry corruption issue, maybe due to a Windows Update long ago. This Win 7 install is very old. I'm reluctant to mess around with registry settings about which I know nothing.

Any help appreciated—it's a stumper for me!

–Alan Perla

THE DOCTOR RESPONDS:

Our temptation is to say wipe clean and start again. Given the age of your Windows 7 installation, it's long past its reinstall-by date (more on that shortly). That said, there are some quick tweaks you can try. First, could it be possible that your playback and output devices have become garbled somehow? Maybe your video player's audio output is being re-routed to your headphones jack, for example—try plugging in a pair of headphones and listening in.

To check this out in more detail, open the Sound Control Panel—check which is your default device on the "Playback" tab and change it, if necessary, by selecting a different device and clicking the "Set Default" button. You may also want to click "Properties" and explore the various tabs to see whether any other settings may need reconfiguring.

If you suspect system corruption, try running "sfc /scannow" under an administrative command prompt to identify potential corrupted system files. Beyond this, messing with the registry's a no-no unless you know exactly what you are looking for—and don't bother with registry cleaning tools; they're more likely to introduce problems than actually solve any.

Instead, take a fail-safe image of your current install with Macrium Reflect Free, use an app such as CloneApp (www.builtbybel.com/ms-apps/cloneapp) to back up key program settings, and make sure your data is also backed up—using Windows Backup & Restore for simplicity—if it's stored on the same partition as Windows. Make sure you've got the latest version of all available drivers for your PC as well as your program installers (if any apps required activating over the Internet, find out what you need to do to transfer the license to the new install—you may need to deactivate them first, or contact the developer to inform them of your plans; take your drive image before you deactivate the license, just in case).

Once done, format the drive, reinstall Windows 7 from scratch (if your install media doesn't include SP1, download a fresh ISO file to burn to disc from www.microsoft.com/en-us/software-download/windows7), then install Macrium Reflect before taking a fresh drive image. Next, install all available updates and drivers, taking a differential drive image, before restoring your backups and reinstalling your programs and settings. Keep testing the sound throughout, but the Doc suspects that wiping your drive clean and starting again from scratch should resolve the problem once and for all.

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THE MINI MAESTRO PC

When it's not about gaming, what can you get on a budget?

SMALL FORM FACTORS are one of our favorite things in the mysterious depths of the tech industry. Year after year, hardware is condensing and we're getting more punch from smaller devices. Yes, we all dream of having a monster machine as part of our setup, capable of rinsing everything we throw in its direction and giving NASA a run for its money. However, there is something intriguing about Mini-ITX builds that we just can't escape from. Having a smaller rig can give you a cleaner setup and more room (obviously), and they look pretty neat, too, in our professional opinion.

It seems as though Mini-ITX systems are nothing but positive news, but that isn't necessarily the case. GPUs such as the impossible-to-grab 3090 cards, for instance, are generally too big for these chassis, so we probably have some waiting to do before we can get cards that powerful in this format. Along with size restrictions on the GPU, there is the overall awkwardness of putting one of these rigs together. It goes without saying that PC building can be a tricky business that makes you want to scream out loud when things go awry. So, if that's a regular occurrence in a normal ATX build, putting together a mini system is never likely to be a bundle of laughs.

We decided to rise to the challenge and build a machine that is more than capable of decent gaming performance and reasonably affordable, all bundled up in a compact ITX case. So, turn the page to see what develops out of our love of small form factors. –SAM LEWIS

MINI MAESTRO PC INGREDIENTS

PART		RETAIL PRICE	STREET PRICE
CPU	Intel Core i5-10600K	$230	$230
GPU	Zotac GeForce RTX 3060 Ti 8GB Twin Edge OC	$600	$1,269–$1,420
RAM	16GB (2x 8GB) Crucial Ballistix DDR4-3600	$94	$94
Mobo	Asus ROG STRIX Z490-I Gaming Mini-ITX	$299	$299
OS Storage	1TB Samsung 980 Pro M.2 PCIe 4.0 SSD	$199	$199
PSU	Be Quiet! SFX L Power PSU 500W	$105	$105
Cooler	Be Quiet! Pure Loop 120mm AIO	$85	$85
Case	Lian Li TU150	$111	$111
TOTAL		**$1,723**	**$2,543**

PRICES CORRECT AT THE TIME OF PRINTING

BUILD IT PG.22

MOTHERBOARD
ASUS ROG STRIX Z490-I GAMING MINI-ITX
WWW.ASUS.COM

Although not recommended for the latest-generation Intel CPUs, this last-gen Z490-I will be more than good enough for our build with a little BIOS update. Yes, this is tedious, and if you can get your hands on a newer Z590-I mobo, go for it, but with a little patience, it's worth the effort. With Intel Wi-Fi 6 AX201 connectivity, support for up to 64GB DDR4 memory across two slots, and two M.2 slots, both supporting SATA and PCIe 3.0 x4, it's still pretty future-proof. Looking this sleek, too, it's a good choice.
• RRP: $299 • Street price: $299

CPU
INTEL CORE I5-10600K
WWW.NEWEGG.COM

One of the main problems with chips right now is the lack of availability, but thankfully they aren't as sought-after as the latest GPUs, and this i5-10600K is in stock at the time of writing. It was a significant CPU from Intel on release as it addressed a key issue at the time: the lack of Hyper-Threading. It introduced 12 threads, for better multithreaded performance in productivity-based tasks like rendering and a more stable experience for gaming. Costing just $230, it offers good performance at an affordable level.

In terms of numbers, it has six cores, 12 threads, and a 14nm architecture, which is still a nice sweet spot and is more than good enough for a processor with this price tag. It also packs a 4.9GHz max turbo frequency. Where it suffers a bit is future-proofing, as it doesn't support PCIe 4.0.
• RRP: $230
• Street price: $230

POWER SUPPLY
BE QUIET! SFX L POWER PSU 500W
WWW.BEQUIET.COM

We've gone with Be Quiet! for our PSU. Its 80+ gold certification with up to 92 percent efficiency has reeled us in. The SFX form factor is recommended for ITX builds, so it's a welcome addition to our rig. With four PCIe connectors, you can hook some decent GPUs up, too. Pairing it with our Be Quiet! cooler should provide quiet overall performance due to their low-noise optimization.
• RRP: $105
• Street price: $105

GRAPHICS CARD
ZOTAC GEFORCE RTX 3060 TI 8GB TWIN EDGE OC
WWW.ZOTAC.COM

We all know Mini-ITX cases are tight on space, so a 3060 Ti is a great fit for our build. This card is a nippy little GPU that offers 1440p AAA gaming with ray tracing. Nvidia claims that it beats the previous superior RTX 2080 Super. That card had a $700 RRP, so this time you're getting more bang for your buck. Nvidia's second-gen RTX technology is introduced by the GPU's Ampere architecture, so you get traditional 3D rasterization combined with ray-traced elements. Just don't pay the current street price.
• RRP: $600 • Street price: $1,269-$1,420

MEMORY

16GB (2x 8GB) CRUCIAL BALLISTIX DDR4-3600

WWW.CRUCIAL.COM

Choosing RAM can be tricky. Other than the fact that there is an abundance of sticks on the market, there are lots of potential configurations when it comes to CAS timings and memory speeds. We have gone down a budget route to keep costs low by choosing Crucial's Ballistix 16GB DDR4-3600 sticks. It's a solid kit that will be more than good enough for our build, but if you want 32GB, it'll cost $188. If you're a Chrome tab hoarder and hate closing down programs, that's probably a good choice.

• RRP: $94 • Street price: $94

CPU COOLER

BE QUIET! PURE LOOP 120MM AIO

WWW.BEQUIET.COM

The clue's in the name, right? As well as being physically compact, we want the sound to be small in size, too. The appropriately named Be Quiet! Pure Loop 120mm AIO will hopefully provide a subtle cooling experience for our CPU. With an all-black design and muted white LED illumination, this is a sleek-looking cooler. The Pure Wings 2 120mm fan operates very quietly, and paired with the Pure Loop aluminum radiator, this is an excellent cooler for compact builds.

• RRP: $85

• Street price: $85

STORAGE

1TB SAMSUNG 980 PRO M.2 PCIE 4.0 SSD

WWW.SAMSUNG.COM

You could say we've gone a little overkill on our SSD, and you'd be right if we'd picked the 2TB variant! Jokes aside, this 1TB model is a beast of an SSD, featuring a very speedy PCIe 4.0 interface, with backward compatibility for PCIe 3.0. it'll deliver great performance across all sorts of tasks, and boasts upward of one million random read/write IOPS and peak sequential read/write speeds of around 7GB/s and 5GB/s respectively. With a PCIe 4.0 CPU and mobo it would make more sense, but regardless, this SSD will be great in our mini build, and perfect for the future.

• RRP $199

• Street price: $199

CASE

LIAN LI TU150 MINI-ITX

WWW.LIAN-LI.COM

Who thought a mini form factor case could look so mean, utilitarian, and solid? This thing looks like it could survive a nuclear war. And scrap your laptop, because this desktop has a handle on top for portability, too. The Lian Li case is a well-put-together chassis for our rig, with decent airflow all around. Our windowless version even has more vents toward the bottom of the side panels, just about where our GPU will sit—perfect. With the PSU mount near the top, there's also a side vent to keep things ice cold.

• RRP: $111 • Street price: $111

BUILDING THE MINI MAESTRO

A MEAN MINI FIGHTING MACHINE.

LENGTH OF TIME: **1-2 HOURS**
LEVEL OF DIFFICULTY: **MEDIUM**

1 BARE BONES

STRIPPING DOWN THE CASE is one of the best things to do at the start of a build. When all the panels are off, it helps you see what you are working with and gives you as much room as possible—a must for cramped ITX systems. Plus, it's a good chance to see the case without all the hectic mess that's about to unfold. Without any glass panels, this chassis looks pretty intimidating, considering its size. Right, let's get into this mini beast. First, pull off the side panels using the concealed push pins. Easy-peasy. The same goes for the top panel. To get the front panel off, remove the plastic clasp pins that secure it before popping it off with the push pins again. Once that's done, we can take out the dust filter and—boom—there's a meaty-looking skeleton (oh, the irony).

4 RAM TIME

UNLIKE NORMAL ATX BUILDS, this ITX motherboard only has two DIMM slots, so we can't really mess up the DIMM priorities. That said, you always have to pay attention to the groove at the bottom of RAM sticks. This little groove in the pins will sit in the DIMM slots in one position only. Before inserting the sticks, make sure the clips on each end of the slots are opened—this is a very easy process. Then slot the sticks into place, push down, and you get a nice satisfying click at each end. There you have it—the DDR4 RAM sticks are secured and ready to battle against all of your Chrome tabs. For our build, we are using two 8GB sticks, which should handle all your browsing and gaming needs.

2 IN GOES THE CPU

AS WITH ALL INTEL CPUS, it's vital that you don't touch the bottom pins. These are super-delicate, so just gently pinch the sides of the chip when placing it on the motherboard. Lift up and raise the retention arm. To do so, you have to push it outward to unhook it, then lift the arm up to reveal the socket, leaving the plastic cover in place. Next, we need to match up the arrow on our Intel chip with the arrow on the motherboard. Once it is positioned correctly, we can lower the bracket back. Pull the retention arm down slowly, so that the bracket slots under the Torx screw, and push the retention arm back securely into the hook again. This will pop the plastic cover off automatically. Just remember to take your time—this is the brain of your build.

3 BRACKET RACKET

TO FINISH WITH THE CPU for now, we need to work on the back of the motherboard. Gently turn the board over, and make sure you work on a soft antistatic surface, checking that no header pins are bearing the weight of the motherboard. Align the cooler backplate to the mobo screw holes, then turn the board back over again. Once this is secured, we can start adding the stand-off screws. Grab the stand-offs and secure them in place. Then add the Intel brackets to the stand-offs to later fit the pump on to. Make sure these are aligned facing outward from the CPU. Tighten the stand-offs diagonally to secure everything. Diagonal tightening ensures good alignment and is a handy tip for all sorts of tasks. Once done, the CPU and bracket can be left alone for now.

5 HEAT STINK

MOVING ON TO THE OTHER FORM of memory in our build, we have our SSD. This Samsung 980 Pro is a neat part of our machine. As with all components, we have to handle it delicately; it's an easy step, but unfortunately not as straightforward as a USB drive install. First, we need to take off the heatsink. This is secured by two screws on the plastic clasp. Loosen these, then slide the ROG-branded clasp off, and remove the remaining screw at the opposite end of the heatsink. Once this is done, we can now gently take the heatsink off and put it aside for now. When doing this, be careful of the seven-pin connector on the underside. The last thing you want is to end up with no storage, right? Make sure the sticky part of the heatsink is facing upward, in case any of the adhesive protection layers have come loose.

6 SSD INSTALLATION

NOW THAT THE HEATSINK is out of the way, we can insert the SSD into the mobo. This M.2 SSD is pretty easy to install. Insert the drive into the connector at a 30-degree angle, making sure it is facing up. If it seems too tight, it probably isn't at the correct angle. We don't want to sound like a broken record, but take your time. Once inserted, it needs to be secured in place with a tiny M.2 screw. Take the heatsink and screw it back down, performing the previous step in reverse, and hey presto: Our SSD is ready for action.

7 MOBO MEET CASE

MINI-ITX BUILDS ARE, as you'd expect, mini. This makes fitting anything into place a lot more awkward and scream-worthy than a standard build. So, as you can imagine, fitting this motherboard was a joy. First off, we need to add the I/O shield to the open case slot. This is the easy part. Then we have to lower the board into place and screw down each of the corners into the case stand-offs, using the screws provided. We recommend using a long-nose magnetic screwdriver. Everyone has dropped screws into a tight space at one time or another, and having a magnetic tool helps a lot when recovering them. With the motherboard installed, it's nice to see the build coming together.

8 ADDING THE RADIATOR

ONE OF THE BIGGEST JOBS for this build is installing our radiator into the case. With little room for maneuver, this can be a particularly frustrating part of the process. Luckily, with the front panel already off, things shouldn't be too tricky. The radiator will go into the front of the case and sit just below the PSU bracket, side-on, in order to fit better beneath the power supply. With the provided wide-top screws, tighten this on to the existing holes in the case with the rubber grommets. Be sure not to overtighten these, because that would nullify the damping effect of the aforementioned grommets. Another tip is to rest the pump block and tubing across the case when fitting the radiator, so they don't get in your way.

11 CASE CABLES

YOU MAY BE WONDERING when we're going to add the GPU. Well, be patient, because we need to attach the remaining case cables first. To start, we'll fit the front I/O cables. Thread these through to the motherboard and fit the USB, USB-C, HD audio, and power/reset switch connectors. The pins for these headers are fragile and can bend with too much pressure. Fit them securely but bear this in mind. One cable out of place can prevent your whole build from booting, so pay close attention to the right headers. Next, we need to fit the AIO cables to the mobo's headers. There will be AIO_PUMP, CPU_FAN, and CHA_FAN connectors for this.

12 REAR CABLE MANAGEMENT

NOW WE CAN ADD THE GPU—despite it being a squeeze in this case, the process isn't too difficult. We need to take off the rear clasp that covers the blanking plates on the back of the chassis by removing the thumbscrew, then take away the blanking plates. Take your GPU and slot it into the open PCIe slot, making sure the connector end lines up with where the blanking plates were. With a gentle push down, it will securely click and lock into place. Screw the rear of the GPU into the case with the screws from the blanking plates. With everything in place, the metal case clasp can be returned and screwed back down.

9 PUMP IT UP

NOW WE NEED to head back to our CPU and add a little thermal paste to its shiny face. Don't be alarmed—this can be quite daunting, but just trust your gut (and us). Grabbing the thermal paste syringe, squeeze a small pea-sized drop on to the center of the CPU, then lower the pump's thermal plate on to the processor, and align it with the stand-offs. Be sure to give it a tiny bit of pressure when resting it in place, to ensure an even spread of the thermal paste across the CPU. Then secure this in position by tightening the screws at opposing corners in order. Our cooling solution is now done, and we can leave the CPU alone.

10 POWER TIME

WITHOUT POWER, we just have a glorified metal box with some fancy interior parts, as cool as it might look. Our power supply has to be located slightly differently from most cases—it has to sit above the radiator, at the front. It screws in at six points to the metal lip on the other side of the case. You need a thin magnetic screwdriver to reach some of the screws, otherwise you can only tighten the four corner ones, which should be sufficient. Once the PSU is secured, plug in the extension kettle cable that's built into the case.

13 BARELY MANAGING

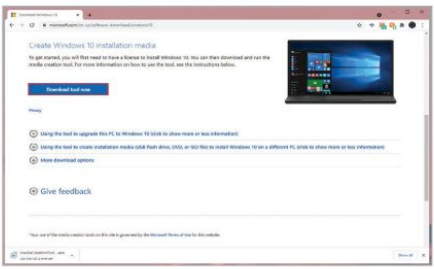
THE LAST STEP INSIDE our case is to connect the PSU cables to the motherboard and GPU. PSU cables can be quite chunky, so if you can spend a little more cash and get custom-length cables that look tidier and fit better, go for it. Run all the cables through the back of the motherboard to keep things away from the front. The motherboard cables can be thick and inflexible, so fitting them at tight angles isn't exactly the most fun task. It's a little cramped in our Mini-ITX case, but what did we expect? After the ATX and CPU cables are installed, we can add the PCIe cables into the graphics card, and that's it for the PC's internals.

14 POPPING PANELS

OUR CASE IS LOOKING a little too naked for our liking, so let's pop the panels back into place to finish off this mini build. We need to focus on the front first and install the dust filter. It's a part that is overlooked by many, but it keeps a lot of dirt and dust from entering our precious machines. Every once in a while, it's a good idea to remove the dust filter and clean it to keep your PC running smoothly. The first panel to pop on is the front, which secures back in place by replacing the plastic clasp pins on either side. Next, put the side panels on, followed by the top. The case is now looking glorious once again, and is ready for the software side of things.

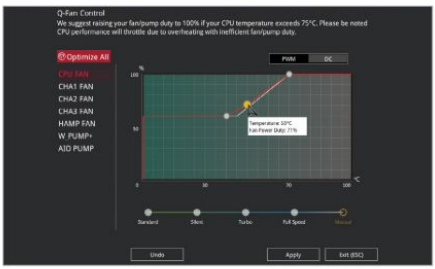
15 WINDOWS USB BOOT

YOU CAN'T REALLY AVOID this step. Every PC setup requires a fresh OS install to get things going. To help with this, it's handy to have another PC ready to download the required software on to a USB drive of at least 8GB storage capacity. Head over to Microsoft's website and search for "Create Windows 10 installation media." Download the file, open up the software, and you will see a screen that says: "Getting a few things ready." After accepting the terms and conditions, wait again. It gives you the option to upgrade that PC now or create installation media for another PC after the second time. Click the second option and proceed. On the next screen, leave things as default, then you can choose which media to install Windows 10 on; click "USB flash drive" to find your drive, click "Next," then it starts to download.



16 OPEN THE BIOS

WHEN THE DOWNLOAD is complete, take the USB drive out and insert it in the new build. Turn the new machine on and you're greeted by the BIOS. Your PC's BIOS interface contains all sorts of vital data and settings that can be altered to suit your needs. A good thing to dive into is the fan curves, which can be altered to make the PC run more quietly—do some research to find what suits your build. Going back to the Windows install, find the boot priority section of the BIOS, and arrange the order to make your USB drive the priority boot drive, then restart the PC. This should boot up the Windows installation and welcome screen for first-time use. Name your PC whatever you want. You don't need to purchase a Windows key yet, so keep running through the setup steps until you get to your fresh Windows 10 desktop.



GOOD THINGS COME IN SMALL PACKAGES

IN AN IDEAL WORLD, we would rather be running an 11th-gen CPU in our new build, with a later Z590i motherboard. This would have certainly made more sense for our SSD. Regardless, our rig is still a more-than-capable fighting machine.

Being a Mini-ITX build, it certainly was more difficult and awkward than a typical ATX case. Fitting everything to the mobo was easy enough, but when it came to fitting parts inside the chassis, some niggling issues arose. The obvious lack of space meant that we had to take things more slowly. Every component we added decreased the available workspace, resulting in even more stress. This is where our long-necked magnetic screwdriver came in. Screwing down the mobo was not as daunting thanks to this tool. The cooler created most of the issues inside the case, largely due to the inflexible nature of the radiator tubes and having to fit said tubing into an already-cramped area. Don't let these issues put you off your own Mini-ITX build, though, as they are fun PCs to own.

Benchmarking

For a mid-budget Mini-ITX build, the CPU and GPU are more than good enough for producing a reliable 60fps-plus experience at high graphical settings. Yes, at 4K the i5-10600K paired with the Zotac GeForce RTX 3060 Ti can't quite reach the frames we would love to see, but it only falls marginally short of the ideal gaming targets. Up against a very similar build with an AMD Ryzen 7 3700X, the Intel build just wins. However, as we said earlier, our Intel chip doesn't support PCIe 4.0, making the AMD chip a better bet for high-speed data transfers.

Another area where our Intel build reigns over the AMD rig is the sequential read and write speeds. This has to be down to our Samsung 980 Pro SSD. Again, it is overkill, and unlike the CPU, this is future-proofed with PCIe 4.0 support. Luckily, the Samsung drive is PCIe 3.0

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	2,185	1,443 (-34%)
CrystalDisk QD32 Sequential Read (MB/s)	3,522	3,542 (1%)
CrystalDisk QD32 Sequential Write (MB/s)	2,988	3,485 (17%)
Middle Earth: Shadow of War (fps)	52	54 (4%)
Total War: Warhammer II (fps)	48	51 (6%)
Shadow of the Tomb Raider (fps)	53	50 (-6%)
Red Dead Redemption II (fps)	47	49 (4%)
Assassin's Creed Valhalla (fps)	38	35 (-8%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an AMD Ryzen 7 3700X, 16GB DDR4 @ 4,133MHz, a Zotac GeForce RTX 3060 Ti 8GB, and a 1TB ADATA XPG Spectrix S40G M.2 PCIe 3.0 SSD. All tests were performed at 4K on the highest graphical profile.

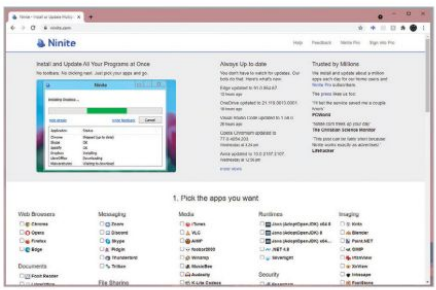
17 UPDATE THE BIOS

YOU DON'T HAVE TO update your BIOS. Usually, if you're buying a brand-new mobo, it should come pre-flashed with the latest version, but if not, boot up a separate PC or laptop and head to the mobo's support page on the manufacturer's website to download the latest BIOS update. Extract it to your USB drive (this needs to be formatted to FAT32; you can use the Windows Installer drive for this), and then placed into a folder named "BIOS." Insert the drive in the new build and restart it. When booting, mash the Delete key until you see the BIOS menu. Click "Use USB to flash BIOS M-FLASH." Accept and run it. The M-Flash screen should appear; click the folder for the BIOS update you created, and open it. Select "Yes" and it begins updating. Leave this to do its thing. Once it's done, the system restarts, and you're good to go.

© ASUS, MICROSOFT, NINITE

18 PC STARTER PACK

AFTER ALL THESE STEPS, you should have a sweet-looking mini machine that's running well. There's just one thing we need to do before we wrap up this build: Install some software. Fortunately, there's a swift one-stop-shop solution to download a bundle of starter software for your PC: https://ninite.com. Head to the site, select which popular programs you'd like to download, and just like magic, everything starts installing. The great thing is that it does this all in the background, it says no to any toolbar and extra junk options, it installs the latest stable version of each app, and it downloads them from each publisher's official site. Does it sound too good to be true? Well, it isn't; it's free and super-easy. Nice work, Ninite.



backward compatible, and works fine in our build. Due to the 980 Pro running at PCIe 3.0 speeds, it's slower than it could be, but does hit the Gen3 speed limit on sequential writes (uncommon for PCIe 3.0 drives). Regardless, this SSD is great and certainly improves our build overall. The Be Quiet! PSU and cooler also help to keep this build running at comfortable levels of sound and temperature.

Final points

Our benchmarks prove you can get a PC with solid performance inside a small form factor without having to spend too much. We're happy with our results, but they do highlight problems in a few areas. If we'd got a newer Asus Z590i board that supports 11th-gen chips, we feel we could have hit that sweet spot of 4K gaming above 60fps. This would also make more sense for our SSD, which would run better with PCIe 4.0 support. Also, if we upgraded those parts, we would swap the existing RAM sticks out for a 2x 16GB kit. On the whole, though, we have produced a neat little gaming machine in an awesome-looking industrial case. The carry handle makes it ideal for LAN parties, too, if they still exist in a post-COVID world.

1 To improve this build, we would get our hands on the Asus Z590i to provide superior future-proofing.

2 With an updated mobo, we would also add an 11th-gen chip. Why not?

3 Luckily cable management isn't the most vital requirement for this windowless build, but aftermarket custom cables could help any future changes by giving us more room to work.

4 Two sticks of 16GB RAM would, again, be beneficial in terms of future-proofing this PC.

SEAGATE
IRONWOLF
12TB
IronWolf
seagate.com
SATA
12TB
BarraCuda Pro
ST12000DM0007
SN: ZCH043GJ
PN: 2GR115-300
FW: DN01
WWN: 5000C500A3DD57B3
PSID: 6UMA78B262HJDAW9PDGUA965J2J991KL
Seagate Singapore Int'l HQ Pte. Ltd
Koolhovenlaan 1, 1119 NB Schiphol – Rijk,
The Netherlands
seagate.com

THE ULTIMATE BACKUP GUIDE

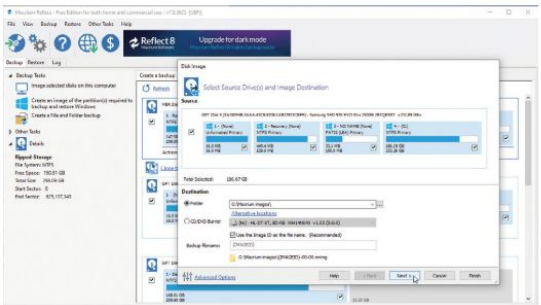
How safe is your data? *Nick Peers* reveals how to set up a foolproof backup plan

HAVE YOU EVER suffered the crippling sensation of data loss? Found yourself having to reinstall Windows from scratch and realizing just how many apps and settings have been lost? The importance of backups cannot be overstated, but does your current backup plan cover all the bases? Is it comprehensive, frequently updated, and spread across multiple locations?

In this feature, we reveal the best free tools for the job, from taking a fail-safe backup of entire hard drives to protecting multiple versions of your data files, so you can undo unwanted changes in addition to protecting the files themselves. We also recommend what to look for in backup devices, and how to safely store your files in the cloud without potentially exposing them to third parties.

Crucially, we step you through the process of backup and restoration, and reveal tools and tips to plug any remaining gaps in your armor. Are you ready to ensure you never suffer another data loss nightmare? Turn the page to get started....

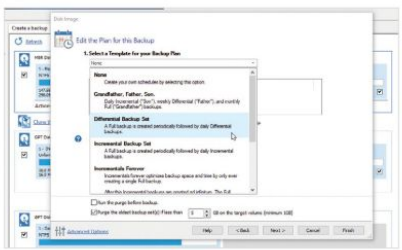
WE'VE BROKEN DOWN the backup process into three key stages. First, you need to take a full, fail-safe drive image to protect everything on your system drive, from your Windows installation and programs to your app settings and any files on the drive. Then you should make a separate, independent backup of your personal data, those files and folders that are irreplaceable, from precious photos to crucial work documents. Finally, we help you securely back up files to your cloud storage while retaining full control of the encryption keys that protect them from unauthorized access.



Macrium Reflect can back up to local and network drives.

STEP 1:
Take a Full Backup

Your first backup will be your most thorough: a byte-for-byte copy of your hard drive in the form of a drive image. This serves a multitude of purposes. Firstly, it's comprehensive. Secondly, it provides you with a working copy of Windows, your programs, and—if everything's on the same drive—your data, so you can roll your PC back to a recent working state in the event of disaster.



Use a template to schedule regular backups.

You need one or more backup drives that are big enough to not only contain a complete—albeit compressed—copy of your main hard drive, but all subsequent backups, too. To minimize the amount of space these backups take, it's important you choose a drive imaging tool that's capable of taking multiple snapshots of your system in such a way as to consume a fraction of the space they'd normally require.

The tool in question is Macrium Reflect Free (www.macrium.com/reflectfree.aspx) and it uses what's known as differential backups to reduce the amount of space your backups consume, making it practical to store weekly or even daily snapshots of your system. Differential backups require one full backup, then they simply record all the changes to your system made since that full backup was taken, resulting in a significantly smaller file (try 10–20GB instead of 120GB, for example). As an added bonus, differential backup jobs complete faster than full ones.

Because each differential backup is based on the latest available full backup, they grow as time passes and more changes are made to your system. The solution is to adopt a set of rolling backups known as a father-son set. You

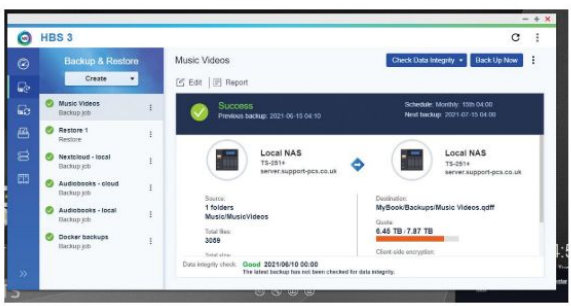
INVEST IN BACKUP DEVICES

You can never have too many backup devices. A rule of thumb is to back up to a minimum of two physically separate drives or locations, and if you have cloud storage, store at least your most critical files online, too (ensuring they're as secure as they can be).

The cheapest backup option is a secondary hard drive—whether internal or connected via USB, it's quick and convenient, but vulnerable to the same fire, damage, or theft as your main PC. With prices slowly tumbling, select the largest drive you can afford (4TB costs around $90) to meet your backup needs both now and going forward.

Ideally, your second backup drive should be in a different room—if not off-site—to provide additional protection against physical threats. Look for a network (NAS) device that can serve as a central backup location for all the computers in your home.

Look for models with two or more drive bays, enabling you to expand capacity or provide additional redundancy in the form of RAID. Models like QNAP and Synology are more like mini-servers than simple network storage devices, giving greater scope to run centralized services such as NextCloud, as well as offering their own tools similar in scope to Duplicati.



Your NAS drive may offer additional backup options.

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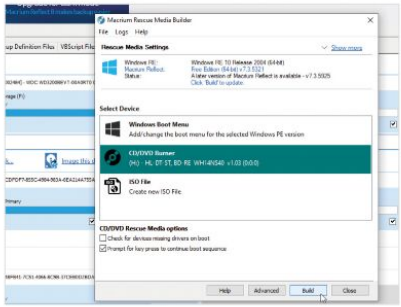
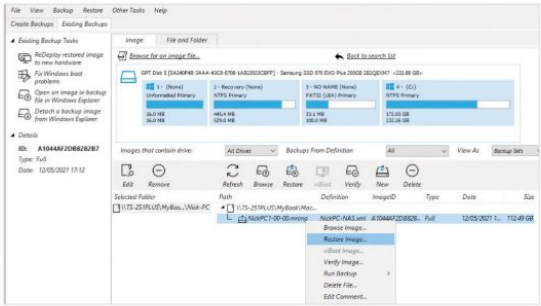




ABOVE: **Don't skip the prompt to build your rescue media.**

RIGHT: **You can restore from within Windows within minutes.**

create a fresh full—or father—backup on a monthly basis, then take differential (son) backups on a weekly basis. To save space, the job retains only a set number of backups: typically, two to four full ones, depending on available storage space, then a rolling set of four to five differential backups.

If space isn't an issue, you could take weekly full backups then daily differential ones, but this obviously consumes more space and you'd have to strike a balance between number of backups and how far back you might want to roll your PC.

Alternately, try the Home Edition of Macrium Reflect ($69.95), which also supports incremental backups; each incremental backup merely records the changes made since the last backup was taken (whether it's full, differential, or incremental), rather than relying on a full backup each time. This allows you to implement a grandfather-father-son schedule: monthly full backups, weekly differential, then daily incremental. For more on Macrium Reflect Home—including a new intra-daily backup feature in version 8 that creates incremental backups every 15 minutes—see our head-to-head on page 92.

Set Up a Schedule

How does Macrium Reflect work? First, launch it. If all your files are stored on a single partition (typically drive C) or you're only interested in taking a drive image of your system, click "Create an image of the partition(s) required to backup and restore Windows."

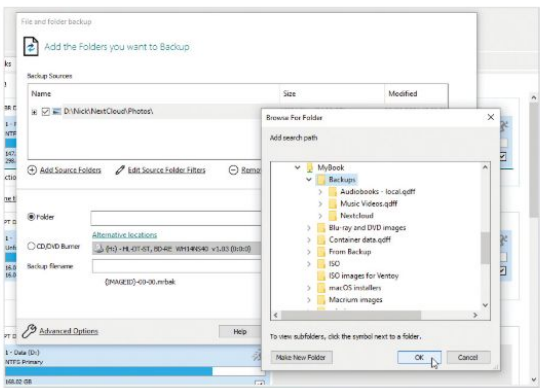
Next, choose where to store your backup. Click "..." next to "Folder" to select a folder on a backup drive (see the box opposite). You can also select a network drive from here—if it requires user/password credentials that aren't stored in Windows, you need to cancel the backup job and choose "Other Tasks → Edit Defaults." Switch to the "Network" tab and click "Add" to select the destination, then enter the credentials so Macrium can seamlessly connect when required. Once done, click "OK" twice and restart the process.

If you're relying on a backup destination that isn't always available, such as rotating external backup drives that aren't constantly plugged in, click "Alternative locations" to choose each location in the sequence you'd like them to be used. Note: If you intend to back up to two separate locations, ignore this, as you need to set up individual jobs for each backup drive.

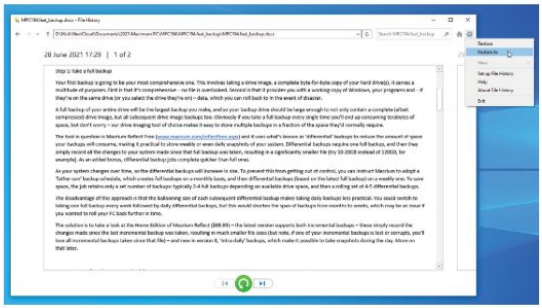
Now click "Advanced Options" to tweak various settings. The "Password" option requires a Home license if you'd like to encrypt your backups, but one recommended tweak is to check the box under "Auto Verify Image" to ensure your newly created backup is validated immediately after it's created.

Once done, click "OK" followed by "Next" to set your backup schedule. You can manually set it using the controls if you want to pair one monthly full backup with weekly differential backups; if you're going for daily differential backups, click the "Template" drop-down and choose "Differential Backup Set" or select the "Grandfather-Father-Son" template if you've purchased a Home license. Then use the "Define Retention Rules" section to determine how long each type of backup is kept (either a set number of backups, or in days or weeks).

Finally, click "Next" then "Finish." Leave both boxes checked, give your backup job a suitable name and click "OK" to take your first backup. Once complete, move on to set up your second backup job if—as we recommend—you're creating a secondary backup for extra redundancy: Create a new job and repeat the steps above, pointing it to your secondary drive



Upgrade to Macrium Reflect Home for more features.



File History enables you to preview files before restoring them.

and tweaking the timings so it doesn't clash with the main backup.

Your next job is to create rescue media—if Windows ever fails to boot, you'll need this to restore your system. If you've not yet been prompted to by Macrium, choose "Other Tasks → Create Rescue Media" to do so. You can burn a DVD, use a USB flash drive (our preferred choice), or add an option to load the rescue environment from the Windows boot menu.

Restore Your Drive Images

Disaster has struck and your PC either won't boot or your hard drive has just died. No matter—if necessary, fit the replacement and reach for your Macrium rescue media. Boot from this and you'll find yourself at a replica of the main Macrium user interface on the "Restore" tab. It should scan your drives for backups, enabling you to choose the one you want (typically the most recent version), or click "Browse for an image file" to locate it manually. Once loaded, choose "Restore Image" to restore the full image, sit back, and wait for the process to complete, rebooting to the point in time where your chosen backup was taken.

You'll notice a "Browse Image" option—if your PC hasn't crashed and you simply want to restore an individual file from it, select this to mount the image as a virtual drive, accessible in File Explorer. Make sure you check "Enable access to restricted folders" to allow you to recover data from user folders and other protected places. Browse the contents for the file you want to restore and copy it back to your main hard drive.

STEP 2:
Back Up Key Files

Next, it's time to tackle your personal files and folders—even if you've included them in your Macrium drive image. A file-based backup allows you to store multiple revisions of a file, giving you the option of reverting to an earlier version and providing insurance against unwanted file changes.

The obvious backup tool here is Windows' own File History—navigate to "Settings → Update & Security → Backup" to set it up. Click "Add a drive" and wait for all visible drives (including network drives) to be displayed. Once done, select your backup drive and review available options: frequency of backups, how long to keep them for, and what folders to include.

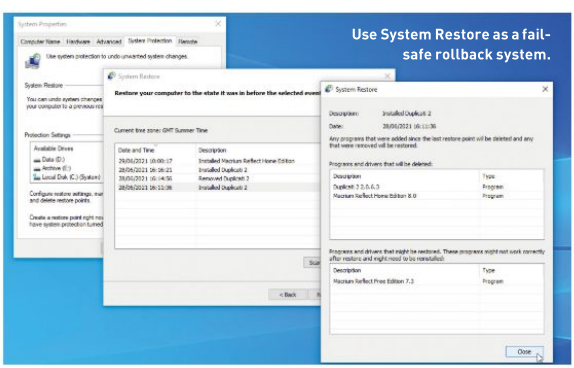
Going forward, File History should keep regular backups of files (including multiple

UNDO UNWANTED SYSTEM CHANGES

You've probably experienced the frustration of troubleshooting a problem that coincides with a recent installation or update, whether app, hardware, or Windows-related. Rather than waste time trying to track down a solution, why not roll your PC back to the moment before that problem started?

This is where System Restore comes in; it's Windows' own snapshot-based backup system that only records system changes, enabling you to roll things back without affecting any other files. It's not received much love in Win 10—and may even have been disabled on smaller hard drives—but can still do a good job of undoing most system changes (with the exception of major feature updates).

You can verify it's switched on and roll back your PC from the same dialog box. Type "restore" in the Search box and click "Create a Restore point." Verify your system drive is switched on under "Protection Settings." You can also manually create Restore points here, although Windows should be smart enough to take a Restore point before major application and hardware changes; click "Create" to be doubly sure.



Should you need to roll things back, click the "System Restore" button. You're shown a recommended (the most recent) Restore point—click "Scan for affected programs" to see what changes will be reversed, followed by "Close" and "Next" to undo those changes. If necessary, select "Choose a different restore point" to go further back in time.

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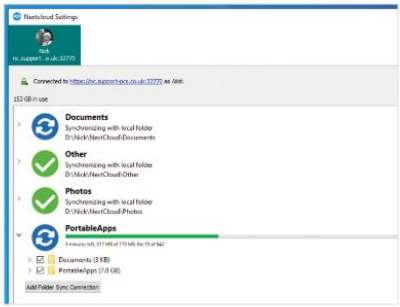


NextCloud works in a similar way to OneDrive and Google Drive.

versions). Restoring files (or earlier versions of a file) is done via File Explorer—navigate to the folder and click "History" under the "Home" tab of the ribbon. Now you can navigate the folder as a timeline, scrolling back to a specific date and time to click on a file to preview it. If it's the version you want, click the green button beneath the preview window to restore it to its original location, or click the settings button and select "Restore to" to create a copy of the restored file in another location.

File History Alternatives

File History is not the most reliable backup tool and is quite slow and awkward. You're also restricted to just one backup location for your files, so regardless of whether you use it or not, you'll want a secondary backup stored elsewhere. If you've purchased the Home edition of Macrium Reflect, click "Create a File and Folder Backup" to back up selected folders following a similar setup wizard to image-based backups.

Another option is to make use of the cloud. OneDrive is already baked into Windows, but you only get 5GB of free storage unless you're a Microsoft 365 user (from $6.99 a month or $69.99 a year), in which case you get a much more generous 1TB of storage. Other cloud providers such as Dropbox or Google Drive offer similar plans.

The upside of cloud storage is that your files are stored securely off-site, protecting them from fire, damage, or theft. There's a question mark, however, over the security of these files—encryption keys are typically held by the cloud storage provider, meaning they could technically hand those files over to a third party.

If you like the convenience of cloud storage—changes are uploaded in the background as they're made, and you have access to previous versions of files, just as with File History—but you don't trust the cloud, you have three basic options. The first is to deploy your own "cloud backup" solution, stored locally on your own network server. Our tool of choice is NextCloud (www.nextcloud.com) and in particular NextCloudPi (https://ownyourbits.com/nextcloudpi/), which can be set up as a Docker instance on a wide variety of hardware. If you need additional help setting NextCloud up, check out our tutorial in the November 2019 issue.

Once set up, you install the client on your PC and configure it to back up whichever folders you like to your network drive. You can also install the client on your phone or tablet for access to files from your cell. The downside is that your data isn't stored off-site, but continue reading for a way to get the best of all possible worlds....

STEP 3:
Secure Cloud Backups

How do you square the circle of off-site backups using your cloud provider without trusting it to keep your data safe? The answer is to use software on your PC that encrypts your data locally before uploading

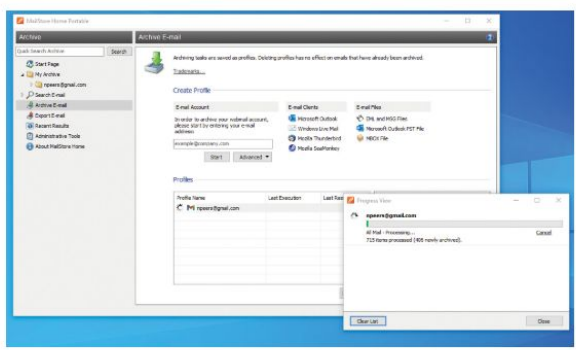
MORE BACKUP OPTIONS

As things stand, you've protected your entire PC and your key files and folders. You've created multiple backups of each. But if you'd like to go further, the following apps and services are all worth considering.

First, want to back up your email? MailStore Home (www.mailstore.com/en/products/mailstore-home/) enables you to not just back up the email you download to your PC through Thunderbird or Outlook, but also works with any online POP3/IMAP account, as well as popular Internet mailboxes such as Gmail and Yahoo! You can easily download all or a portion of your mailboxes, and are also able to browse and search your archive offline, enabling you to free up space elsewhere.

We recommend installing it as a portable version, allowing you to keep everything in a single folder you can subsequently include in another backup—for extra peace of mind.

What about program settings? CloneApp (www.builtbybel.com/ms-apps/cloneapp) supports a wide range of popular programs and settings, and comes in two versions: one for regular desktop apps, the other handling apps you've installed from the Microsoft Store. Again, it's portable, so everything is easily backed up into one place. Use it to transfer settings to a new Windows installation or PC; for regular day-to-day backups, Macrium has all your app settings covered.



MailStore Home backs up your emails to a searchable archive.

it to the cloud, using encryption keys only you have access to, thus putting your files beyond the reach of your cloud provider and any third party that might try to access them.

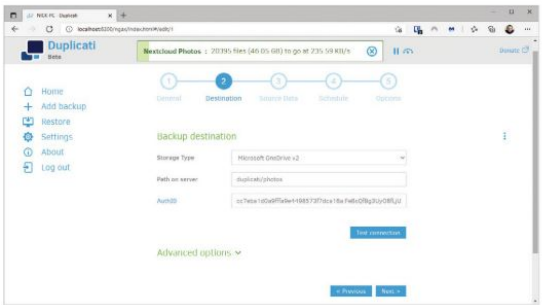
There are two basic approaches to encrypting cloud backups. If you want to save files directly to the cloud, you'll need Cryptomator (https://cryptomator.org), which can encrypt files on the fly using your own personal encryption keys. Use it to set up one or more encrypted "vaults," which are folders stored inside your cloud folder. Anything placed in here is encrypted before it's uploaded. It's simple to use, there are (paid-for) mobile apps to access these files on the go, but it works best when used sparingly, perhaps with ultra-sensitive files rather than all your cloud-hosted files and folders.

Introducing Duplicati

Another approach is to use your cloud storage purely as an off-site backup location. The encryption process is the same: Your personal encryption keys scramble your backups before they are uploaded, in order to put them beyond the reach of your cloud provider. For this we recommend the free and open-source Duplicati (www.duplicati.com).

Duplicati is a block-based backup tool, splitting your data into small chunks that are AES-256 encrypted behind your choice of password, compressed, and then sent to your backup location: a proprietary cloud provider such as OneDrive or Dropbox, a local drive, or a server accessible through a range of popular protocols such as FTP or WebDAV. Duplicati supports file versioning, so once the initial backup is done, all changes are recorded incrementally to speed up file uploads and minimize the storage space used.

Connect to your cloud account when setting up Duplicati.



The program runs as a standalone tool, with access through both a graphical web interface and the command line for those who need it. You can install it directly in Windows, Linux, or macOS, or deploy it to a QNAP or Synology NAS via Docker.

Configure Your Backup

Once installed, Duplicati resides as an icon in your Notification area. Right-click this and choose "Open" or simply go to http://localhost:8200 in your browser to skip through the first-run wizard. If you install Duplicati on a shared PC, everyone has access, so you're first prompted to set up a password to restrict access to the program's web interface. Click "Yes" even if you're the only user, to review the program's main settings and tighten security where necessary.

It's worth remembering that backing up directly to the cloud is much slower than backing up to a local or network hard drive. Duplicati's default configuration will see it saturate your bandwidth attempting to upload as quickly as possible, so it needs reining in to prevent it from crippling your Internet connection while it's in use. Start by scrolling down to "Default options" and click "Pick an option" next to "Add advanced option." Select "Asynchronous-concurrent-upload-limit" under "Core Options" and set it to 1. When done, click "OK" and, if you set a password (which should be a strong one and stored in your password manager), you're prompted to log in with it.

Once you've configured Duplicati to your tastes, click "OK" to return to the main screen. Click "Add backup" to create your first backup job: Leave "Configure a new backup" selected and click "Next." Give your backup a suitably descriptive name and an optional description. Choose your level of encryption—the default AES-256 built-in option is best for most—then enter a strong password with the aid of a password manager. Click "Next."

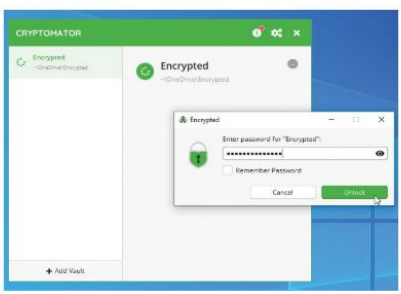
By default, your computer is chosen as the place to save your files—click the "Storage Type" drop-down menu to reveal all available remote options. After selecting your online storage, click the "AuthID" box to follow the prompts to link Duplicati to your chosen remote storage account. After the AuthID code has been generated and copied into the box, you need to manually enter the path on your server—for example, "/duplicati/"—and then click "Test connection," creating the folder when prompted.

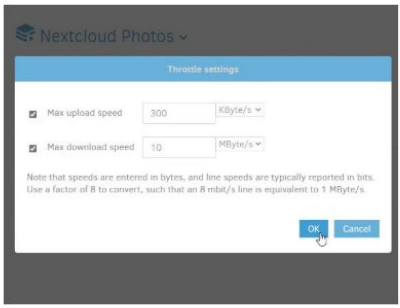
Choose What to Back Up

Once created, click "Next" to use the file picker to select which folder(s) to include in your backup. When it comes to selecting what to back up, you can exclude unnecessary files from folders using a combination of simple (Exclude) and complex (Filter) options. Exclude options include check boxes to ignore hidden, system, and temporary files, plus an option to ignore files over a user-specified size.

The Filters option is more complex—this is a combination of keywords or wildcards, with a choice of exclude or include filters, such as "Exclude directories whose names contain" or "Exclude regular expression." You can add as many filters as you need but

Encrypt files before uploading them to the cloud.




Nextcloud Photos
Throttle settings
Max upload speed
300
KByte/s
Max download speed
10
MByte/s
Note that speeds are entered in bytes, and line speeds are typically reported in bits. Use a factor of 8 to convert, such that an 8 mbit/s line is equivalent to 1 MByte/s.
OK
Cancel

Set connection limits to prevent Duplicati overwhelming your Internet connection.

be careful setting these—you may end up excluding files that you want to protect. Consult the Duplicati manual (https://duplicati.readthedocs.io/en/latest/—select "Articles → Filters") to find out how to apply them.

Next, choose your backup schedule—by default, backups are taken daily at 13.00, but you can edit this to your satisfaction, backing up as often as every few minutes if you so wish. Click "Next" again when done. Leave the "Remote volume size" alone, and then choose how long backups are kept using the "Backup retention" drop-down—if in doubt, choose "Smart backup retention." Finally, click "Save."

Set Bandwidth Limits

Your first backup job appears on screen, ready to start at the time you've set. You'll see a "Run now" shortcut next to it, but before clicking it you need to perform an additional step to prevent Duplicati from crippling your connection. Click the speedometer icon at the top of the screen to limit how much bandwidth Duplicati can use. We recommend capping your upload speed to 50 percent of your available bandwidth—for example, a 5Mbit/s connection is the equivalent of around 625KB/s, so cap the upload speed to 300KB/s. Also check the download limit box, even if you decide to leave it set to the default 10Mb/s.

Once done, click "Run Now" and leave Duplicati to its own devices—a progress bar appears indicating the current upload speed and how many files (and amount of data) remain to be transferred. If your Internet connection feels sluggish, return to the speedometer to set a lower upload limit. Depending on the size of the folder(s) you're backing up, the initial process could take days if not weeks to complete, so if you've not already done so, take a local backup, too—either with Duplicati or another app—as a form of insurance.

You can add as many backup jobs as you need (although you should stagger them so they don't attempt to all run at once)—edit an existing backup job by clicking the down arrow next to its name to reveal a list of clickable options. Choose "Edit" under "Configuration" to access the same wizard you used to set up the backup, and make whatever changes you need.

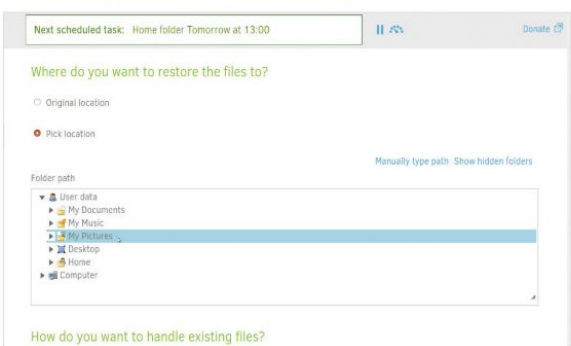
We also recommend backing up your Duplicati configuration files—in case your computer dies, and you need to restore your files to another PC. Expand each backup job's settings and click "Export" under "Configuration." Leave "To File" and "Export passwords" selected, check "Encrypt file" (and supply a password) to protect it, then click "Export." Store the file somewhere safe. Should the day come when you need to restore your data—whether a specific version of a file or everything after a catastrophic crash—check out the box below.

RESTORE YOUR DUPLICATI BACKUPS

How do you restore data from Duplicati backups? If you've not had to reinstall Windows from scratch, simply open Duplicati in your browser, expand the relevant backup job, and click "Restore files" under "Operations." If you've had to reinstall Duplicati from scratch on a new computer or install, and you backed up your configuration files, choose "Restore from configuration," click "Next" to select your configuration file, and enter your password. On clicking "Next," the backup job should be restored, and you can start the restoration process from there. If you didn't back up the configuration file, choose "Restore → Direct restore from backup files" and click "Next." This is a similar process to setting up your backup: Choose your provider, enter the destination path, and link to the account. You then input the password you used to encrypt the backup, and that unlocks its contents for restoration.

Whichever option you choose, use the file picker to choose which folders to restore (select the top-level folder to select everything in your backup). You can search for specific files and folders by keyword, too. If you're looking to roll back to an earlier version of a file, use the "Restore from" menu.

Click "Continue." You can restore to the original location or select a folder path to restore to. By default, existing files are overwritten, but you can save a copy with a timestamp in the specified location. Look out for the "Restore read/write permissions" box—ordinarily you'll want to preserve these, so check this before clicking "Restore" and waiting for the files to copy back to your PC.



You can restore files to another location with Duplicati.

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THE MACHINE LEARNING REVOLUTION

According to the hype, artificial intelligence will soon be capable of anything. *Jeremy Laird* examines the true nature of machine learning

IT'S THE NEXT BIG WAVE of computing. So says Intel of artificial intelligence (AI). If anything, that's underselling it. According to some evangelists, AI is the key to unlocking almost every major problem humanity faces, from a cure for cancer to limitless clean energy. Less optimistic observers, including philosopher and neuroscientist Sam Harris, see AI as one of the most pressing existential threats to the survival of mankind. Either way, as Dr. Emmett Brown would put it, it's pretty heavy.

Even a brief analysis of the implications of AI quickly takes on epic proportions. Back at the more practical end of the epistemological scale, getting a grasp on current commercial implementations of AI can be equally baffling. Machine learning, deep learning, neural networks, Tensor cores—keeping track of the processes and hardware, not to mention the jargon, associated with AI is a full-time job.

So, the long-term impact of AI may be anyone's guess. But, in the here and now, there are plenty of questions that can at least begin to be addressed. What is AI in practical computing terms? What is it used for today? What kind of hardware is involved and how are AI workflows processed? And does it add up to anything that you as a computing enthusiast should care about? Or is it just a tool for Big Tech to bolster their balance sheets?

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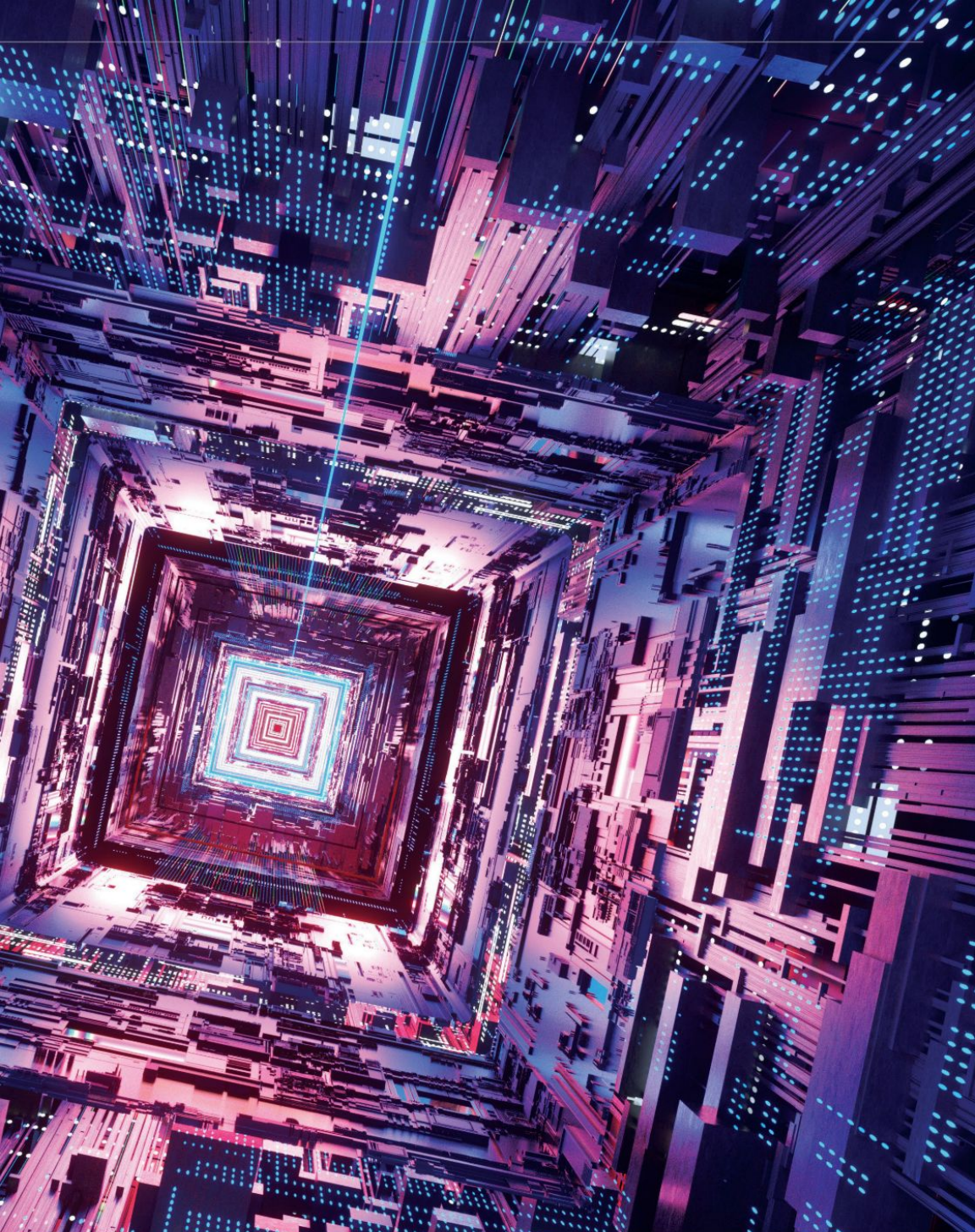
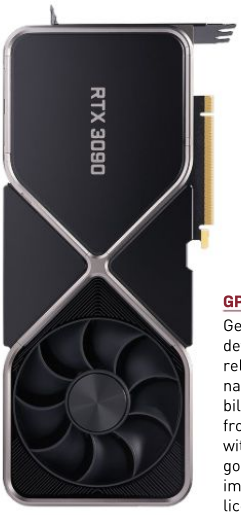


BUZZWORDS AND BULLCRAP or the greatest paradigm shift in the history of computing? What, exactly, is artificial intelligence, or AI? According to the hype, AI won't just radically revolutionize computing. Eventually it will alter almost every aspect of human life. Right now, however, defining AI and determining how relevant it really is in day-to-day computing, that's not so easy.

Put another way, we can all agree that when, for instance, the self-driving car is cracked, it'll have a huge impact on the way we live. But more immediately, when a chip maker bigs up the "AI" abilities of its new CPU or GPU, does that actually mean much beyond the marketing? Whether it's a graphics card or a smartphone chip, is the addition of "AI" fundamentally different from the usual generational improvements in computing performance?

Taken in its broadest sense, AI is any form of intelligence exhibited by machines. The meaning of "intelligence" obviously poses philosophical problems, but that aside, it's a pretty straightforward concept. Drill down into the specifics, however, and it all gets a lot more complicated. How do you determine that any given computational process or algorithm qualifies as artificial intelligence?



Nvidia's new RTX 30-series graphics cards sport third-generation Tensor cores for accelerating AI workloads.

WHAT DEFINES AI?

One way to define AI is the ability to adapt and improvise. If a given process or algorithm can't do that to some degree, it's not AI. Another common theme is the combination of large amounts of data with the absence of explicit programming. In simple terms, AI entails a system with an assigned task or a desired output, and a large set of data to sort through, but the precise parameters under which the data is processed aren't defined. Instead, the algorithms are designed to spot patterns and statistical relationships, and learn in a trial and error fashion. This is what is otherwise known as machine learning and it's usually what is meant when the term AI is used in a commercial computing context.

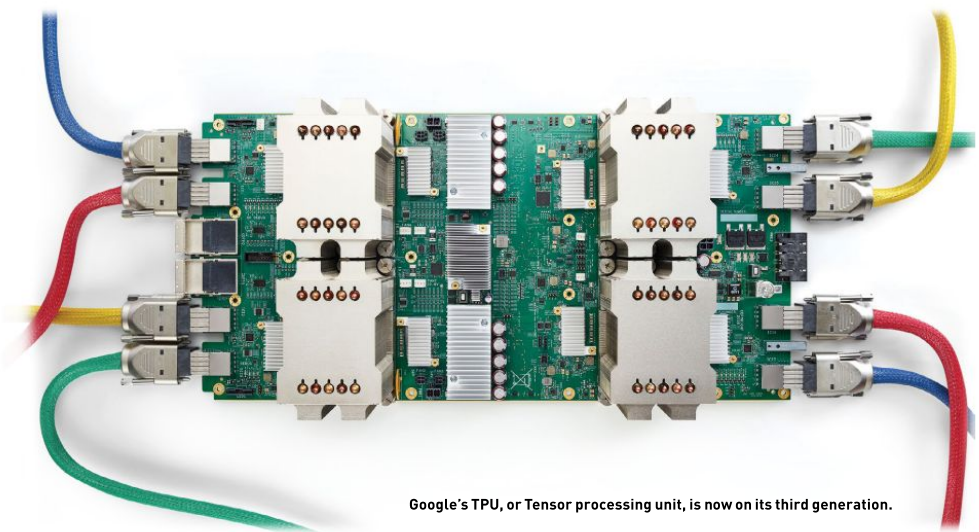
A good example of how this works in practice is natural language processing. A non-AI approach would involve meticulously coding the specific rules, syntax, grammar, and vocabulary of a given language. With machine learning, the algorithmic rules are much less specific and all about pattern spotting, while the system is fed huge amounts of sample data from which patterns eventually emerge.

GPT-3

Generative Pre-trained Transformer 3 (GPT-3), developed by San Francisco-based OpenAI and released in 2020, is just such a machine learning natural language system. It was trained using billions of English language articles harvested from the web. GPT-3 arrived to much acclaim, with *The New York Times* declaring it "terrifyingly good" at writing and reading. In fact, GPT-3 was so impressive, Microsoft opted to acquire an exclusive license in order to use the technology to develop and deliver advanced AI-powered natural language solutions, the first of which is a tool that converts text into Microsoft Power Fx code, a programming language used for database queries and derived from Microsoft Excel formulas.

GPT-3 goes beyond the usual question-and-answer Turing Test tricks. It can do things such as build web layouts using JSX code in response to natural language requests. In other words, you type something like "build me a page with a table showing the top 20 countries listed by GDP and put a relevant title at the top," and GPT-3 can do just that. It showcases both the ability to adapt and a system that's based on processing data rather than intricate hand-coded rules.

However, GPT-3 is also a case study in the limitations of machine learning. Indeed, it's debatable whether GPT-3 is



Google's TPU, or Tensor processing unit, is now on its third generation.

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AI-powered autonomous driving features, such as Tesla's Autopilot, have proved more difficult to develop than expected.

actually intelligent at all. Arguably, it could all be considered something of a digital conjuring trick. That's because GPT-3 and its machine-learning natural language brethren do not understand language—or, ultimately, anything else—at all. Instead, everything they do is simply based on statistics and patterns.

By analyzing enormous quantities of written text, statistical rules that output plausible responses to natural language queries can be created without any need for what, on a human level, would be classed as understanding. And that, essentially, is the basis for most—if not all—machine learning, whether it's applied to the problem of natural language processing and voice assistants, self-driving cars, facial recognition, or recommending products and content to customers and consumers. It's just pattern spotting on an epic scale. From Amazon's Alexa to Tesla's Autopilot, the fundamental approach is the same. You can find out more about the limitations of existing AI systems in the boxout page 43, but if we've established the rough parameters of AI, the

A CHIP-DESIGN GURU AND THE UNFATHOMABLE FUTURE OF AI

CPU ARCHITECT AND TECH LEGEND JIM KELLER ON MACHINE LEARNING

Is there anybody involved in chip design with a better résumé than Jim Keller? He's the brains behind not only AMD's first CPU architecture to really sock it to Intel (that'll be Hammer back in the 2000s), but also the driving force that led to Zen and AMD's renaissance in the late 2010s. He sired Tesla's Autopilot chip, set Apple on the path to building arguably the most efficient client CPUs available today, and more recently had a stint at Intel.

Now Keller is heading a start-up, Tenstorrent, specializing in custom chips for accelerating AI workloads. That fact alone is enough to lend serious credibility to the field of AI and machine learning. According to Keller, there are now three kinds of computers. First there were CPUs. Then came GPUs. Now, the AI computer has arrived.

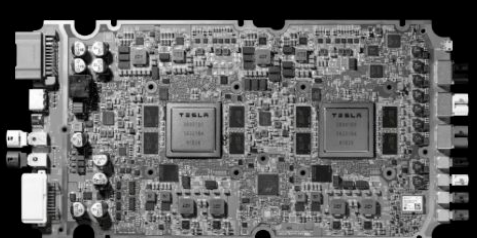
"In the beginning," Keller explains of the development of computers, "there was scalar math, like A equals B plus C times D. With a small number of transistors, that's all the math you could do." As the transistor count of computer chips grew exponential, so did the complexity of math that was possible. First, vector math was possible, then matrix multiply. Today, the complexity is pushing chip design in a new direction.

"As we get even more transistors, you want to take big operations and break them up. If you make your matrix multiplier too big, you begin to waste energy. So you build this optimal size block that's not too small, like a thread in a GPU, but not too big, like covering the whole chip with one matrix multiplier." The result, according to Keller, is an array of medium-sized processors where "medium" means a processor capable of four tera operations per second. What Keller is describing is the next step in AI computing from specialized blocks that accelerate matrix math, like Nvidia's Tensor cores, to a new type of chip that accelerates what he calls "graph" computing.

The other piece of the puzzle is software, an element Keller clearly views as just as important as hardware, and which he refers to as Software 2.0. "The first time I heard about Software 2.0 it was coined by Andrei Karpathy, who is the director of AI and autopilot at Tesla. His idea was that we're going from a world where you write programs to modify data to where you build neural networks and then program them with data to do the things you want. So modern computers are programmed with data. It means a very different way of thinking about programming in many places where AI has had so much success. I think in the Software 2.0 future, 90 percent of computing will be done that way," he says

The most fascinating of Keller's prognostications is the future unfathomability of AI computing. "If you go look inside a neural network that's been trained and ask why is this particular element given, say, the weight 0.0015843, nobody knows," Keller explains. "There's phenomena now where you have a machine learning system with inputs and outputs. There's an AI black box in between the inputs and outputs, but if you look in the box you can't tell what it means. You don't understand the math or the circuits underneath."

Keller concedes that already the full complexity of a high-end AMD, Intel, or Apple chip is almost unfathomable, but if you dig into any given detail, someone knows what it does. If Keller is correct, it won't be long before 90 percent of computing is beyond the wit of man. Whether it's intelligent is another matter.



Tesla's custom Autopilot chips are just one of many achievements in Jim Keller's stellar back catalog.

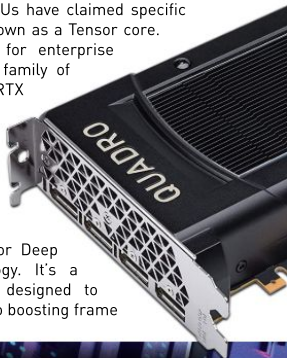
next question is how it's implemented and what kind of hardware is required.

HARDWARE REQUIREMENTS

At one end of the scale is what you might call AI infrastructure, the supercomputers and cloud installations used to do the epic data analysis and generate the pattern maps or models. At the other? Client devices that use those models in practical applications.

It's the latter that's of most interest to us as PC enthusiasts. Put another way, the question this all begs is whether AI is a clearly identifiable computing paradigm that benefits from dedicated hardware in client devices such as PCs and phones. Does it mean anything to have something akin to "AI compute cores" or specific parts of a chip expressly designed to accelerate AI applications? Or is AI on the client level largely marketing spin?

For sure, chips from the big players in computing are increasingly sold on the strength of their AI prowess. The most obvious example on the PC is Nvidia's graphics chips. For several generations now, Nvidia's GPUs have claimed specific AI capabilities thanks to a feature known as a Tensor core. First seen in Nvidia's Volta GPUs for enterprise applications and then in the Turing family of gaming GPUs, sold as the GeForce RTX 20-series, Nvidia's Tensor cores are now in their third generation in the Ampere GPUs, otherwise known as the GeForce RTX 30-series.



DLSS

The most familiar application for Nvidia's Tensor cores is its DLSS, or Deep Learning Super Sampling technology. It's a graphics upscaling implementation designed to deliver higher image quality while also boosting frame

ON-DEVICE VS. IN THE CLOUD
WHAT'S THE BEST WAY TO PROCESS AI?

Ask anyone for a real-world usable example of AI and they'll probably pick one of the big three big digital assistants: Amazon Alexa, Apple Siri, or Google Assistant. But are such services better run locally on a device or up in the cloud?

Take Apple's iPhone. You might be surprised just how much of the familiar iPhone functionality is driven or at least enhanced by AI. It's used, for instance, to distinguish between intentional inputs and accidental brushes against the capacitive touchscreen.

Machine learning algorithms are also used to schedule charging, to improve long-term battery health, and to sort images in the Photo app into ready-made galleries and identify people using facial recognition. Depending on the age of a given iPhone, it may also be able to use machine learning to composite multiple images to create a single ultra-high quality photo. Even Apple's predictive text is enhanced by machine learning.

What's particularly interesting about Apple's approach to AI is how it fits into the contest between AI processed locally on devices compared to up in the cloud and in data centers. Broadly, Apple is moving away from cloud AI to on-device AI. Already, Apple has dedicated features like the Neural Engine in its chips that can be used to do things like image analysis locally on-device. In future, that approach will increasingly become the norm. The next iteration of Apple's mobile operating system, iOS 15, for example, will pull the processing for the Siri voice assistant out of the cloud and put it on to the iPhone handset.

Unlike Google, Amazon, and Facebook, Apple prefers on-device AI to using data centers.

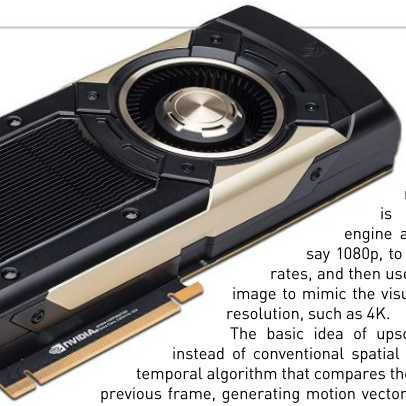
Partly, that's down to privacy concerns, which Apple sees as a major distinguishing feature between its products and services and the likes of Amazon, Google, and Facebook, which Apple argues all depend on knowing as much about you as possible.

"This addresses one of the biggest privacy concerns for voice assistants, which is unwanted audio recording," Apple said. But it begs the question of whether on-device AI can possibly compete with the huge machine learning models stored in data centers. Apple, predictably enough, says that it can.

"I understand this perception that bigger models in data centers somehow are more accurate, but it's actually wrong," says John Giannandrea, Apple's senior vice president for machine learning and AI strategy. "It's actually technically wrong. It's better to run the model close to the data, rather than moving the data around. And whether that's location data, like what are you doing, or exercise data, what's the accelerometer doing in your phone, it's better to be close to the source of the data. It's also privacy preserving."

Latency is another advantage of on-device AI. Over to Giannandrea: "You're taking a photograph, and the moments before you take a photo with the camera, the camera's seeing everything in real time. It can help you make a decision about when to take a photo. If you wanted to make that decision on the server, you'd have to send every single frame to the server to make a decision about how to take a photograph." That just doesn't make any sense, Giannandrea says. It's far better done on the device.

Of course, services that entirely depend on huge datasets will remain in the cloud for the foreseeable future. And given Apple's emerging stance on privacy, plus the company's undoubted prowess in developing both devices and the chips that power them, the on-device sales pitch definitely makes for a distinct proposition. But it remains to be seen whether consumers really care about privacy and if a Neural Engine or matrix math accelerator in an iPhone really compete with exaflops of dedicated Google AI hardware in a data center.



Nvidia's GV100 GPU was the first to get AI-accelerating Tensor cores.

rates. The basic idea is to render a game engine at a lower resolution, say 1080p, to achieve higher frame rates, and then use DLSS to upscale the image to mimic the visual quality of a higher resolution, such as 4K.

The basic idea of upscaling isn't new. But instead of conventional spatial upscaling, DLSS is a temporal algorithm that compares the current frame to the previous frame, generating motion vectors that can be used to enhance image quality during upscaling. As it happens, DLSS is also a neat example of how AI infrastructure interfaces with client hardware.

DLSS is based on a supercomputer-powered per-game training process that compares millions of high-quality reference frames rendered at 16K (15,360 by 8,640 pixels) to scaled outputs, incrementally generating improved algorithms. Once the "training" process is complete, the DLSS scaling model for a given game is included in Nvidia's graphics drivers, then accelerated by the Tensor cores in Nvidia RTX graphics chips, allowing DLSS to be applied in real time to a running game engine.

And you know what? At its best, DLSS does things that other upscalers simply cannot achieve. Nvidia's arch-rival AMD recently released a more conventional non-AI alternative to DLSS, and while it works well enough, it lacks the magic of DLSS. Nvidia's AI upscaler isn't flawless, but it comes closer to convincingly mimicking native resolution rendering than anything else.

WHAT'S IN A TENSOR?

So, what exactly are Nvidia's Tensor cores and how do they differ from more familiar circuitry like pixel shaders in GPUs or integer and floating point units in CPUs? Is there really something specific about them that justifies the "artificial intelligence" angle?

In fundamental computational terms, Tensor cores accelerate matrix operations by performing mixed-precision matrix multiply and accumulate calculations in a single operation. These kinds of calculations are mathematically straightforward, but computationally intensive on general-purpose computing architectures, such as CPU cores. The "Tensor" branding, for the record, is an appropriation of the mathematical term of the same name that refers to containers of data of which matrices

By now, Waymo was expecting to have a fleet of at least 60,000 autonomous cars. It actually has 600.

© WAYMO, NVIDIA

THE LIMITS TO AI
THIS HAS ALL HAPPENED BEFORE...

Way back in the 1950s, at the dawn of computing, researchers assumed a machine with human-level intelligence might be possible within 10 years, 20 at the most. Here we are, 70 years later, and true AI arguably isn't any closer to reality. So, should we file AI along with a cure for cancer and nuclear fusion as yet another technology that somehow recedes from reach with every step forward in understanding?

Certainly, the limitations of current pattern-spotting machine learning are becoming increasingly apparent. In 2015, Elon Musk, Tesla's head honcho among his other accolades, confidently predicted self-driving technology would achieve "complete autonomy" by 2018. He wasn't alone in making that kind of bold prognostication. In 2016, Ford predicted that it would be selling "fully autonomous" commercial vehicles for ride sharing applications by 2021.

But here we are and driverless cars feel no closer to reality than they did a decade ago. Arguably, the challenge feels even greater. Earlier this year, John Krafcik, chief executive of Google's driverless car subsidiary Waymo, underscored the difficulty of developing driverless technology.

"It's an extraordinary grind, a bigger challenge than launching a rocket and putting it in orbit around the Earth because it has to be done safely over and over and over again," Krafcik said. That's quite a turn around from 2018, when Waymo was planning to unleash 62,000 driverless minivans by the end of that year. At last count, Waymo's driverless fleet numbered just 600 vehicles.

"When we thought, in 2015, that we would have a broadly available service by 2020, it wasn't a crazy idea," Krafcik explained. "If we've got one prototype, then we can get to mass production in just a couple of years, right? This was a position of—I wouldn't say ignorance—but a lack of information and a lack of experience. We've become very humble over these last five years."

Self-driving car technology is not the only area where the promise of AI has failed to deliver. Far from it. *The Economist* magazine reckons enthusiasm for AI across industry is stalling, in part due to being overhyped, citing a survey of European AI start-ups that found 40 percent were not actually using AI at all.

More broadly, *The Economist* reckons AI faces two core problems. The first is, surprisingly, a lack of data. Despite our increasingly digitized lives, critical data is often incomplete. Tracking COVID-19 transmission without a comprehensive record of individual movements, for instance, has proved impossible.

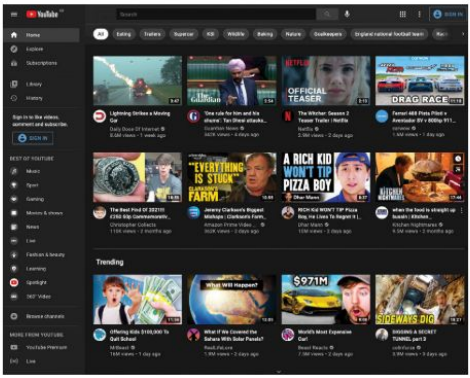
The second problem is even more challenging. Existing AI typically depends on pattern spotting and does certain tasks like image recognition and language processing far better than old-school software with hand-coded rules. But such systems are not "intelligent" as the term is traditionally understood. There's no cognition or reasoning, no ability to generalize, just a narrow ability to do one thing very well. In fact, the scope of existing AI systems is so narrow there is now doubt whether fully autonomous cars will ever be possible, such is the complexity of coping with the unpredictability of driving in the real world on real roads—and even slightly off them.

are a subset, and also includes scalars and vectors. Scalars can be thought of as zero-dimensional tensors composed of a single number, vectors are a one-dimensional tensor composed of a single column of numbers, and matrices are two-dimensional tensors made up of both rows and columns of numbers.

Modern CPUs do have floating point units with SIMD or single instruction multiple data extensions designed, among other things, to accelerate calculations involving matrices. But that hardware remains multipurpose rather than purely dedicated to matrix math. Highly parallelized GPUs are even better at crunching matrices, but even they employ broadly programmable units, such as Nvidia's CUDA cores, that are not narrowly and exclusively designed for matrix math.

Except, of course, Nvidia's Tensor cores. Nvidia's GV100 chip, as found in the Titan V graphics card, was its first GPU with Tensor cores—640 of them to be precise, rated at 110TFLOPS. By way of comparison, the GV100 also has 5,120 of Nvidia's conventional CUDA cores, which can also do matrix math. The combined computational output of those CUDA cores comes to just 27.6TFLOPS, despite being far more numerous and eating up the majority of the die space on the GV100 chip. When it comes to matrix math, then, Tensor cores are orders of magnitude more efficient.

What's more, the matrix math performance of Nvidia GPUs is growing fast. At one end of the scale, the GeForce RTX 3060, currently the lowest-end RTX 30 series GPU available, roughly matches the GV100 in terms of Tensor core performance. Meanwhile, Nvidia's latest high-end enterprise GPU, the A100, has around triple the Tensor core performance. As it happens, the A100 chip is the basis for Nvidia's Perlmutter supercomputer, claimed to be the world's fastest AI machine. Created in partnership with HP, it packs no fewer than 6,159 A100 GPUs, delivering nearly four exaflops of compute power, a number so huge that it's difficult to, well, compute.



It might not always feel like it, but recommendation engines, such as that used by YouTube, are powered by advanced AI.

INTEL, GOOGLE, AND APPLE

Anyway, AI-specific logic in chips from Nvidia's competitors is also all about matrix math. Intel's upcoming Sapphire Rapids Xeon processor for servers, for instance, packs what Intel is describing as a new "built-in" AI acceleration engine called Intel

The home of technology
techradar.com

The upcoming Sapphire Rapids architecture for Xeon server chips will be the first to get Intel's AMX matrix math acceleration extensions.

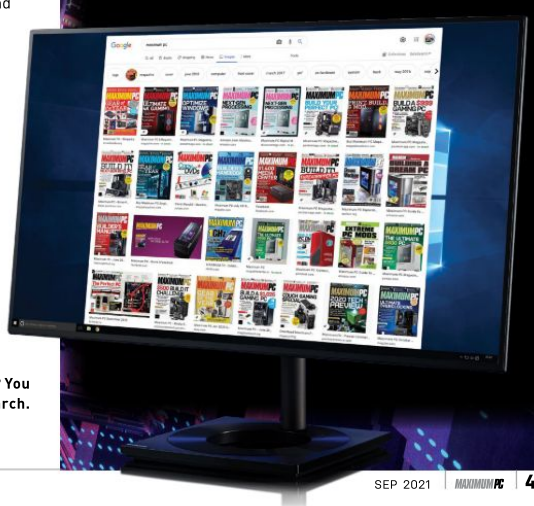
Digital assistants such as Amazon Alexa are what probably spring to mind when thinking about existing AI applications.

Advanced Matrix Extensions, or AMX for short. For now, Intel isn't giving away much by way of specifics. But it's thought that AMX essentially amounts to a matrix math overlay on top of Intel's existing AVX-512 vector engines.

Coincidentally, Apple has its own matrix-optimized AI blocks in its in-house chips, beginning with the A13 SoC in the iPhone 11, and revised for the new A14 and M1 chips, the latter found in the latest MacBook Air, entry-level MacBook Pro, Mac Mini, and iMac. Those blocks are also dubbed AMX, although in this case that refers to "Apple Matrix," as opposed to Intel's Advanced Matrix Extensions. Actually, Apple's chips confusingly have yet another AI-accelerating block, known as the Neural Engine. For more on that and the broader concept of neural networks, head for the boxout on the right.

Meanwhile Google's TPU, or Tensor Processing Unit, which is a whole chip dedicated to matrix or tensor math, is now on its fourth generation, having debuted in 2015. Granted, the Google TPU is not something you'll find in your PC or phone, but it's another example of how the computing industry is converging around a common approach to AI acceleration, and confirmation that AI is a meaningful computing paradigm, not merely a marketing term. Google says those TPUs, incidentally, were used to identify and process all the text appearing in its entire StreetView database in Google Maps in under five days.

Overall, AI presents an intriguing dichotomy. On the one hand, there is no doubting the huge impact it is having on computing and in turn the way we live our lives. AI and machine learning can do things no other computing paradigm can match. On the other, it's hard to dispel the sense that it's misdescribed. Machines can certainly learn to do some seemingly clever things, but it's debatable if there's any true intelligence involved. If it isn't, if all this really is purely pattern spotting, AI may be destined to remain siloed into narrow if ever more numerous competencies, the full promise and peril of a more generalized artificial intelligence tantalizingly out of reach.



Want to experience the power of neural networks? You probably already have done, courtesy of Google's image search.

NEURAL NETWORKS
THE LOW-DOWN ON DEEP LEARNING

Computer scientists have been dabbling with neural networks since the 1950s. Back then, researchers in the field predicted the technology would lead to machines capable of walking, talking, consciousness, and even self-replication. If that seems like a stretch, there's no doubt neural networks are now one of the most important elements of the broader AI effort. But what are neural networks, how do they work, and what are they used for?

Neural networks are a type of data structure loosely inspired by networks of biological neurons, where the digital neuron is a mathematical function involving weighted sums. The larger an input's weight, the more that input affects the neuron's output. The clever bit is the network's ability to "learn."

Using the example of image recognition, if the network of neurons correctly classifies an image input, the weights used to achieve the correct identification output are increased and vice versa, incrementally improving the ability of the network to correctly identify images. The problem, in those early days of neural networks, was the available computing power.

The big practical breakthrough came with the ability to dramatically increase the "depth" of trainable layers in the network. Enter the notions of deep learning and backpropagation. Very long story short: The use of multiple layers of inputs and outputs, the "deeper" the better, each feeding or propagating back into and improving the accuracy of the layers below, radically expands the scope of trainable networks.

An early example of this approach came in 1998 when it was used by researchers at AT&T to recognize hand-written numerals and thus automate the process of paying in checks. As the researchers concluded, the approach using automated learning yielded far better results than "hand-designed heuristics."

As the availability of compute power has exploded, so the applicability of deep learning neural networks has expanded. By 2013, Google was using it at the core of its online image search and it has since been rolled out for everything from smartphones to smart cars. But perhaps its greatest attribute is the ease with which it can be applied. Over the last few decades, the building blocks of neural networks have been fine-tuned, making the training relatively straightforward given sufficient quality data. All of which implies that the future of AI is as much and maybe even more about access to data as improved algorithms.

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CENTERFOLD

PERFORMANCE GEAR LAID BARE

1 SOUND ON

The integrated speakers on the Anzu sit on the underside of each arm, and provide surprisingly good sound quality. They're not going to match a proper set of headphones, but combined with the mic, they work great for Zoom calls. The *Maximum PC* team concluded in our weekly Hangouts meeting that using these won't draw the ire of your coworkers like using a crappy AirPod mic will.

2 FEELING BLUE

Although they might sound somewhat hokey, blue-light glasses are a legitimate purchase for anyone with a lot of screen time. The Anzu's standard lenses filter out 35 percent of incoming blue light, which doesn't make for a hugely distracting viewing experience but helps to reduce eye strain. They're ideal for those who suffer headaches after long stretches in front of the computer.

Razer Anzu

BLUE-LIGHT FILTERING GLASSES for streamers and gamers (or anyone who spends over five hours a day staring at a monitor) aren't new, but they're surging in popularity. Companies such as Blux have released prescription blue-light blocking specs in partnership with esports teams; now Razer has entered the fray with a unique approach.

The Anzu smart glasses are a union of blue-light filtering lenses and smart assistant tech, which consists of built-in headphones, a microphone, and invisible touch controls. They connect to your device of choice via Bluetooth, linking automatically to a paired device when you unfold them.

The Anzu specs were designed with gamers in mind, demonstrated by a gaming mode that triggers ultra-low-latency audio and a game-oriented sound mix. Naturally, they're well equipped to work with smart assistant tools such as Google Assistant and Siri. A variety of intuitive touch controls function via hidden pads on each arm.

The glasses feel like a piece of concept hardware, made of glossy plastic, with blue status LEDs on the inside of each arm. They come in round or rectangular frames, and our rectangular pair is very comfy to wear for long periods. **–CHRISTIAN GUYTON**

3 THROWING SHADE

The Anzu glasses come not only with blue-light filtering lenses but an additional pair of polarized sunglasses lenses that can be easily swapped by popping the lenses out of the frame. These provide 99 percent protection from UVA and UVB light, transforming the Anzu into a sleek pair of smart sunglasses.

GAMES OF THE DECADE

The last 10 years have really pushed gaming to new frontiers; *Ian Evenden* highlights the most important games of the 2010s

THE LAST DECADE was something of a golden age for PC gaming. It saw the gap between consoles and gaming PCs widen even further, as the hardware we play on became more powerful and capable than ever before.

But it also saw the emergence of the blockbuster game as a rival to the kind you see in theaters. In 2007, 14 years ago, *Halo 3* took the largest launch-day sales of any media property at that time, with first-day sales of $170 million, overtaking the likes of *Harry Potter* and *Spider-man* at the movies. Since then, the numbers have only got bigger, and in 2017, *PlayerUnknown's Battlegrounds* took $900 million on its first day, toppling 2013's *Grand Theft Auto V* ($815m).

GTAV—a game that launched on Xbox 360 and has appeared on three generations of consoles—is also emblematic of the past 10 years in gaming, as the decade has seen more in the way of remakes, remasters, and straightforward rereleases than at any other time. This doesn't mean that the game industry has become less creative, but it's a reflection of how much more expensive and intensive it has become to develop a triple-A, big-budget game in the years that saw the rise of ray tracing, the consolidation of multicore processors, and 4K screens become something you can pick up for a few hundred bucks. Development teams are now huge, budgets reach into the hundreds of millions, and games can be in development for many years before being released, unfinished.

Here, then, are our pick of the PC games of the last decade, in no particular order.

Grand Theft Auto V

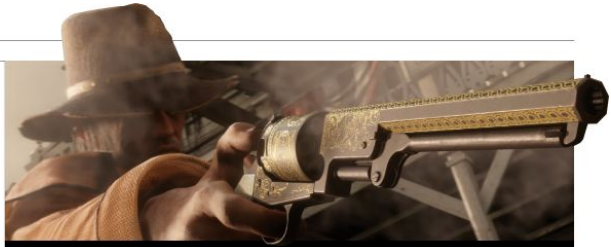
Ridiculous fun, as long as you can square your conscience with playing the bad guy. Rockstar's satire on western society takes all the best things about *The Wire*, *The Sopranos*, and a dozen other box sets and sets them loose under a blazing sun, where they interact and self-destruct with gore-infested glee. Playing as three street-level characters up against governments and billionaires grounds the absurdity, while a never-ending multiplayer mode of hits and heists keeps players coming back.

- **Released: 2013**
- **www.rockstargames.com**

© ROCKSTAR

The Elder Scrolls V: Skyrim

Ten years old, and still the most recent mainline *Elder Scrolls* release. Another game that's spanned console generations, picking up the *Special Edition* and modding it heavily is the definitive way to play on PC today. Modern hardware makes graphical updates that once brought GPUs to their knees fly, and it's still big enough to get lost in. Fighting giants and dragons while auroras whirl overhead is as vital today as it was at release.
• **Released: 2011** • **https://elderscrolls.bethesda.net**



Red Dead Redemption II

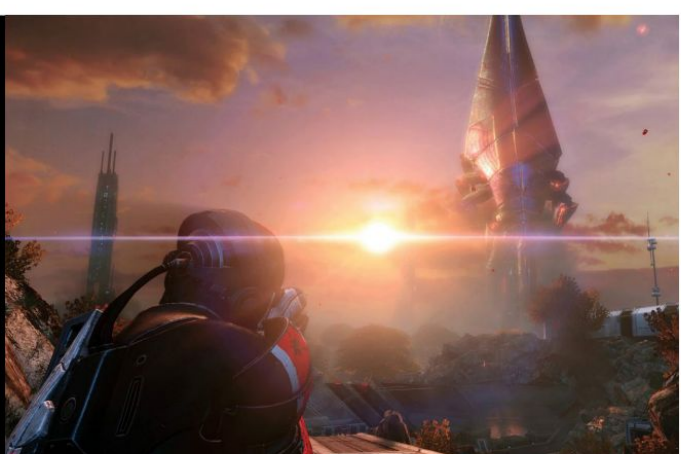
Rockstar slows down, makes a campfire, and contemplates the prairie. Then quick-draws, shoots six bad guys in the head, and helps a nice lady find some dinosaur bones. Less frantic than *GTA*, with a good line in character-driven action and some of the best sunsets we've yet seen, it was tough on PC hardware in 2018, and GPUs are only just catching up in 2021. A game of long horseback journeys punctuated by graphic violence, poker games, train robberies, and just about everything else you've seen in a Western, it feels, unusually for a videogame, as though it comes from a place of love.
• **Released: 2018** • **www.rockstargames.com**

Portal 2

Evil robots, celebrity voice actors, and computers powered by potatoes may get in the way, but *Portal 2* is still the perfect example of game designers showing off how clever they are. And it's great entertainment. Along with the portal gun, which links two surfaces within the level, *Portal 2* adds colored gels that create or impede movement, but that's it. It still requires you to think in three-dimensional corkscrews, with level after level of lethal escape rooms often appearing deceptively simple but full of thought and planning. It's not a long game, but it stays with you.
• **Released: 2011** • **https://store.steampowered.com**

Mass Effect: Legendary Edition

It was 2007 when Commander Shepard first made contact, but the culture of remakes has brought him (or her) around again, with a graphical upgrade and three-for-one (plus DLC) pricing model, and these RPGs mixed with a heavy dose of third-person shooter are still better than many released since. The first game is a tight, focused introduction, but the second opens out to envelop a whole galaxy under threat. It's improved by what it's lost—unwieldy vehicle sections and annoying weapon specializations have been cut, as has multiplayer—as much as by what it's gained (the trilogy's ending is the controversial *Extended Cut* version), and if you've not played before is an absolute steal.
• **Released: 2021** • **www.ea.com**



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Starcraft II

Technically just a little too old to be here, but the final mission pack *(Nova Covert Ops)* was released in 2016, and the entire game is simply awesome. With three beautifully balanced races—brutal mechanized Terrans, advanced psychic Protoss, and swarming insectoid Zerg—each with a full single-player campaign, and some of the best strategy multiplayer in the business, they don't make 'em like this any more, and that's a shame.

- Released: 2010
- www.blizzard.com

Minecraft

The game that sold 200 million copies and captivated even more kids is a bizarre mix of Lego and a rock-hard survival game. Get your walls built before nightfall or the zombies will get you. The creative side far outweighs the survival gameplay, however—there's nothing like it for building floating castles—and it's still getting updates, with the last major one in 2020 adding new biomes, resources, and monsters. Not just for kids.

- Released: 2011
- www.minecraft.net

The Witcher III: Wild Hunt

A beautiful, dark fantasy, open-world RPG, it was *The Witcher's* stories that drew, and continue to draw, players in. Your attention is pulled this way and that as you try to follow missions but get waylaid by villagers asking you to kill the neighborhood monsters, and a political story bigger than anyone plays out around you. The *Blood and Wine* expansion is particularly good for this, and is bundled in the *Game of the Year* edition.

- Released: 2015
- https://thewitcher.com

Forza Horizon 4

The PC has a lot of racing games, and *Horizon 4* may not be the most accurate in terms of simulation, but for sheer freewheeling entertainment, it's hard to beat. Set in an England apparently unaware that a major racing tournament is taking place on its roads and across its fields, *Horizon 4* mashes together online and offline play, and has you compete in varied events across four very different seasons to build "influence," which you use to unlock new events, and so on. It also releases weekly events, hides rare cars in barns, rewards you for ludicrous combo jumps, and generally makes it impossible to get bored.

- Released: 2018
- https://forzamotorsport.net

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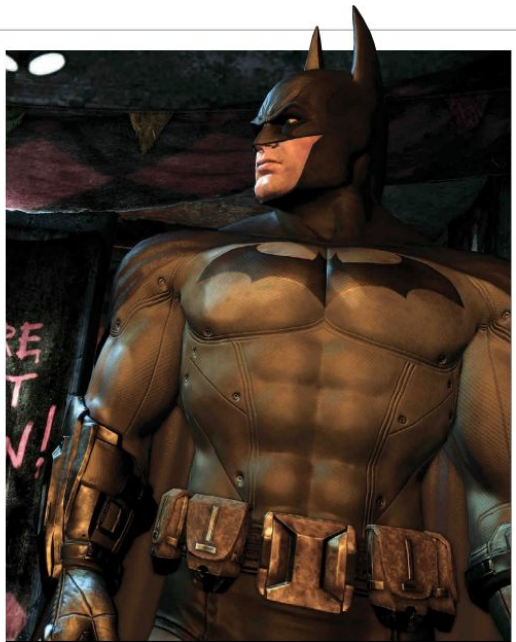
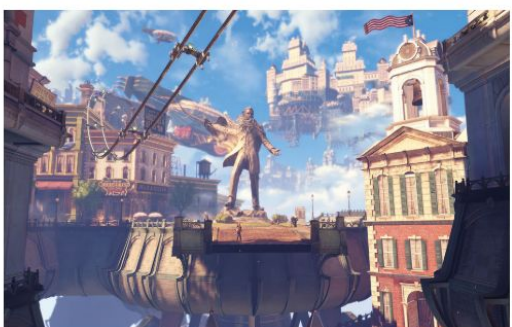


Batman: Arkham City

Rocksteady's Batman doesn't mess around. He's crunchingly physical, the only way to deal with crime being with his fists and boots. The middle game in a trilogy, *Arkham City* takes the focused violence of *Arkham Asylum* and roots it in a free-roaming city, *Escape From New York*-style, meaning you can zip around the rooftops doing puzzles and platform challenges before silently descending and devastating your foes.

• Released: 2011 • www.warnerbrosgames.com



BioShock Infinite

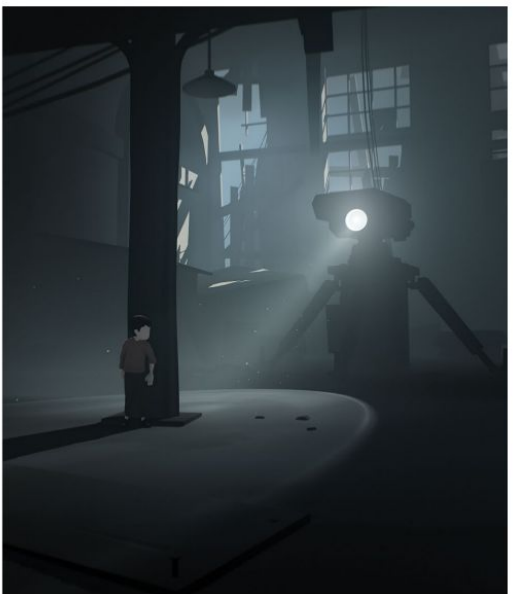
A flying city full of racists, robots that look like presidents, sharks jumped, and fridges nuked. *BioShock Infinite* is a lot of surface stretched over some thin scaffolding—the repetitive nature of the arena battles soon becomes apparent—but if you don't peer too deeply and try not to care that nothing makes sense, it's an atmospheric and artistically unrestrained romp through unfriendly skies.

• Released: 2013 • https://2k.com

Divinity: Original Sin II

The closest thing we've yet seen to tabletop RPG gaming on a computer, your PC plays the DM with a smirk, letting you try just about anything you like, and ruling fairly on whether you will succeed. So, if you want to eat corpses, there's a class for that, and if you want to use the teleport skill to essentially cheat, well, you can do that, too, as long as you make the dice rolls. The best thing since *Baldur's Gate II.*

• Released: 2017 • https://divinity.game



Inside

There is no other game in which you can pull an eel out of the backside of a pig, and for that alone *Inside* deserves to be on this list. The story of a frail boy on the run from ruthless, murderous, law enforcement, it quickly transforms into a mysterious stealth adventure in which nothing is adequately explained. The ending, a roaring, cathartic reversal of everything that has gone before, is worth the multiple deaths it will take to get there.

• Released: 2016 • https://playdead.com

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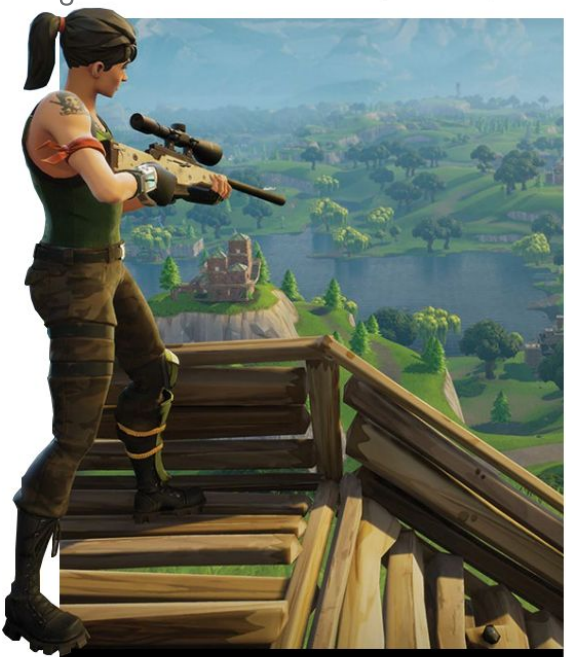

Fortnite

Shooting zombies, and each other, while laying traps is the essence of *Fortnite*, each match opening with a period of scavenging before building a massive base you have to defend. Having the high ground is a big part of combat, so harvesting material and building like a mad gopher will get you a long way. There are skill trees, constant content drops, and a permanent state of progression by the tiniest fractions of an inch. Battles have 100 players, and while it's possible to play for free, you'll get much more in the way of a reward if you buy a Battle Pass.
• Released: 2017 • www.epicgames.com

Dota 2

This retail release based on a *WarCraft III* mod was used to get Steam into places it hadn't gone before, so the free, 5v5 arena battler ended up with huge player numbers. The idea is to lay siege to the enemy base by picking one of 112 heroes, having an appreciation of the advantages of each and how it will team with the other four players on your side. It makes 4D chess look easy.
• Released: 2013 • www.dota2.com

Hades

Zagreus, son of the Greek death god of the underworld, wants out. This is not going to be easy, however, as every lost soul and mythical monster stands in his way. You repeatedly try to leave the underworld only to be beaten, return to the start, become more powerful, talk to your dad and pat his dog, then try again. It's wonderfully written and the combat hits just right.
• Released: 2020 • www.supergiantgames.com

Control

The Oldest House is a New York skyscraper with a secret, and you just walked in off the street into the middle of it. An extradimensional intelligence is trying to enter our universe through a slide projector, and as Jesse Faden picked up a weird gun at the beginning of the game, the building has decided it's up to her to stop it. A Metroidvania that involves plenty of backtracking and unlocking of new areas, you'll soon be flying, telekinetic, and in possession of an eldritch grenade launcher. There's nothing like it.
• Released: 2019 • www.remedygames.com

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Dishonored

A strange, steampunk setting and some of the lumpiest faces in gaming make *Dishonored* stand out from the crowd—if there was a crowd of games like this. Part *Hitman,* part *Deus Ex,* all weird, you play a supernatural royal bodyguard trying to restore order to his city. Leave bodies everywhere and the game gets harder, so slipping through unnoticed is key; that's easier said than done.
• Released: 2012 • https://bethesda.net

Assassin's Creed: Odyssey

In one of the defining series of the decade, *Odyssey* remains one of the better sneaky-RPG games ever made. Not only is the world huge, but it's filled with things to do, and the Mediterranean sunshine makes it an engaging place to do your killing. The first AC game to offer a choice of characters, its plot runs from the mundane to the mythical in a lively, dynamic world.
• Released: 2018 • www.ubisoft.com

Dark Souls 2

The best of the three, at least until *Bloodborne* gets its inevitable PC release, and the PC port *(Scholar of the First Sin)* looks much better than the console games ever did. Alongside the famously hard bosses and clanging combat, there's a real sense of exploration in a world that's far from open. You're pushed in a direction, despite being able to fast travel and return to a hub, and the game is better for this. You always know something terrible is coming, so you edge forward behind your shield the first time, before getting more powerful and confident as the game goes on.
• Released: 2014
• https://en.bandainamcoent.eu

Wolfenstein: The New Order

This could have been *Doom,* but the first new *Wolfenstein* game since 2009 has something special. MachineGames takes the setting into a Nazi-dominated 1960s, piles on the retrofuturism, and literally takes you to the Moon and back. The combat is ferocious, the guns and enemies suitably over the top, and Blazkowicz is more than just a smirking bullet-sponge.
• Released: 2014 • https://bethesda.net

Destiny

What is *Destiny?* An online sci-fi first-person shooter in which you perform the same actions again and again in a constant search for better equipment for your class-based character. The action has moved to *Destiny 2,* and new content drops fairly regularly, while PvP arena combat keeps your skills sharp. For a long-running online shooter it's easy to pick up and start playing.
• Released: 2014 • www.bungie.net

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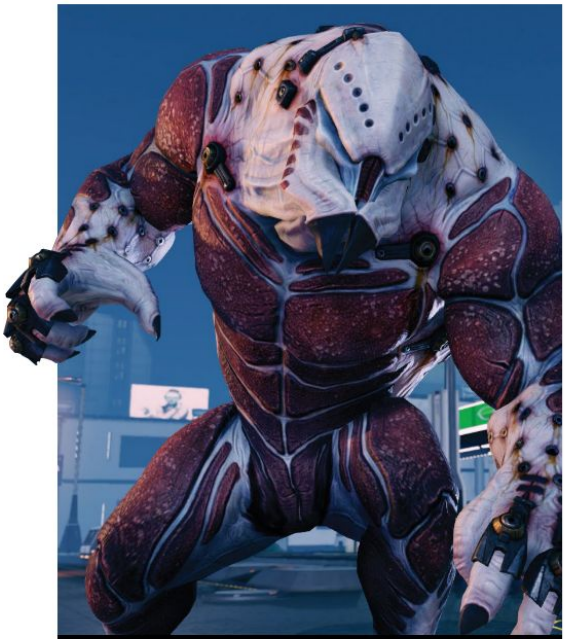
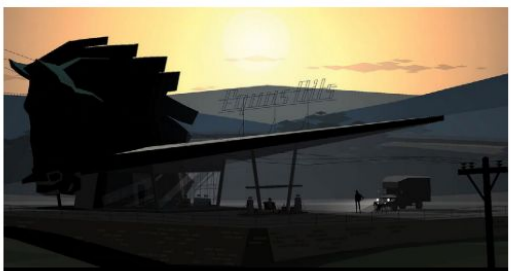


XCOM 2

XCOM has lost its battles against the alien invaders, who have taken over Earth and are creating alien/human hybrids. You no longer have to make the bickering nations of the world happy, you just have to put bullets, lasers, and plasma into alien faces, rescue kidnapped scientists, dig out new sections of your base, and discover where the alien commanders are hiding. The heart of the game is the precise turn-based combat, in which cover is everything, having the high ground can be the difference between victory and a total wipe, and a 95 percent shot can miss.
• Released: 2016 • https://xcom.com

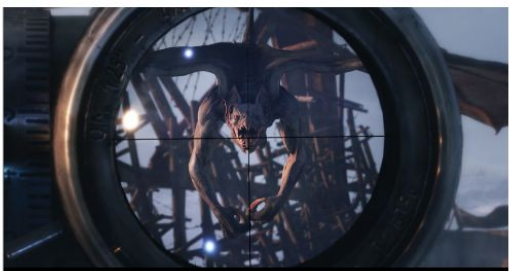
Tomb Raider

The beginning of a trilogy that failed to build high on these solid foundations, the reimagined *Tomb Raider* is perhaps the best refresh of a well-known character we've seen, showing Lara Croft at the start of her career, taking away the sexualization, and leaving a delicate girl just as likely to shake and whimper as she is to pepper an enemy with rifle fire. She grows into a mass murderer, but takes her first kill hard, and even when forced to hunt deer for food, she clearly feels every death deeply. It's an interesting character portrait as much as an acrobatic shooter.
• Released: 2013 • https://tombraider.square-enix-games.com



Kentucky Route Zero

Another magical-realist title that's about the characters you meet rather than shooting them, you're not having much of an effect on this linear world, just drinking in the sort of working class stories you rarely see in videogames. The greatest sights are saved for the moments when new characters join your group, all looking for something that may not even exist.
• Released: 2013 • http://kentuckyroutezero.com



Metro: Exodus

Gaming's most claustrophobic series busts out of the Moscow sewers and into brilliant, ray-traced sunlight as you search for the source of a transmission that was previously jammed. While it loses some of its character by coming out of the dark, you still sneak around plenty, using pneumatic weapons to silently kill slave masters, mutants, and enormous bat-things.
• Released: 2019 • www.metrothegame.com

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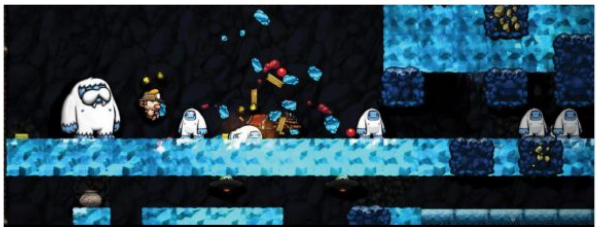


Spelunky

A remake of a 2008 freeware original, this game of procedurally generated cave exploring and shotgun-archaeology is a highly accessible roguelike. There's permanent death on offer, and the difficulty level is high, but the rewards are great, even if that's just satisfaction gained by not dying for a while. No two trips are the same, so once you've played for hundreds of hours, you'll see the game's blocks and creatures everywhere you go.

• Released: 2013 • https://spelunkyworld.com

Halo: The Master Chief Collection

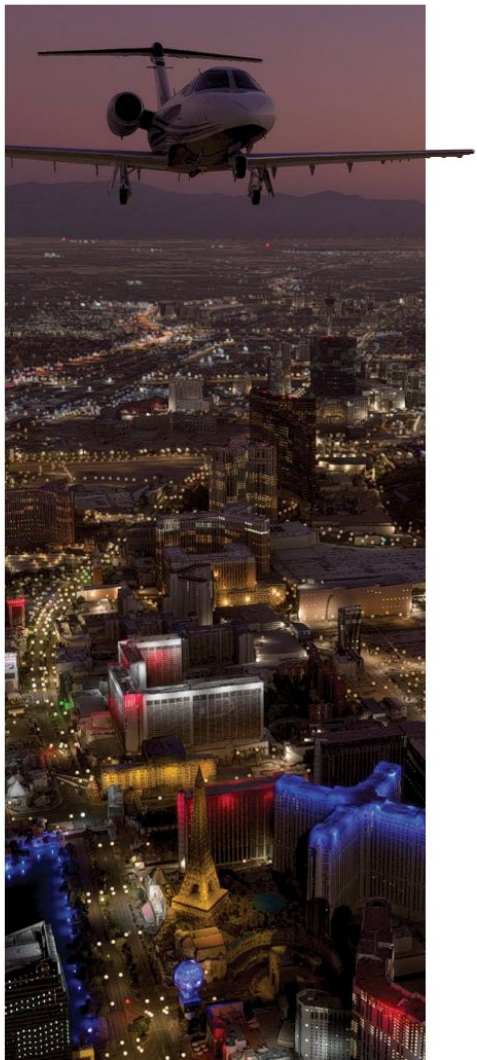
A slight cheat, as each game here except *Halo 4* was released before 2012, but they're some of the best sci-fi shooters ever. You get upgraded graphics and netcode, with complete redesigns of the audio and cutscenes. What's not changed is the shooting, AI, and handling, so the starting pistol is still the best weapon, and on higher difficulties, the Elites still put up a good fight. There's still the Flood and the Library, but that's only one part of one game.

• Released: 2019 • www.halowaypoint.com

Disco Elysium

A point and click! In 2019! Waking up on the floor of a hotel room minus your pants and nursing a hangover so bad you can't remember who you are, this strange police procedural casts you as an amnesiac cop with a murder to investigate. It's as much about putting yourself back together as it is investigating the chap hanging from a tree. You can choose a new name, and the way you respond to the people you speak to molds your new personality.

• Released: 2019 • https://discoelysium.com



MS Flight Simulator

Is it even a game? In these troubled times, the kind of clear headspace attainable from simply flying a plane through calm, sunny skies is the sort of service we should probably be paying 10 times as much for. It needs some strong hardware, but the live air traffic control chat, streaming map-based landscapes, and real-time weather effects add up to something that is exactly as realistic as you want it to be, and sends you off with a huge sense of achievement once you pull off one of the trickier maneuvers. Like landing.

• Released: 2020

• www.microsoft.com

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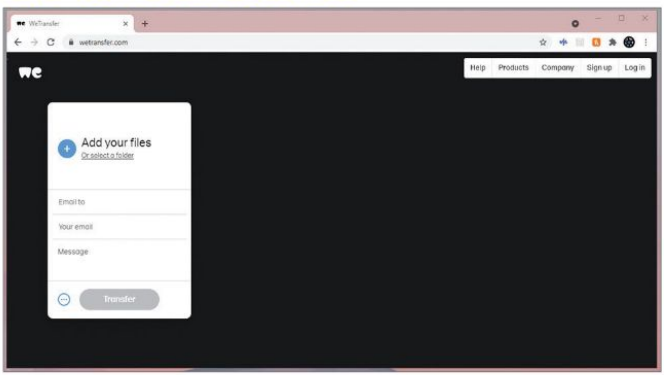
forums.pcgamer.com

PC GAMER

HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

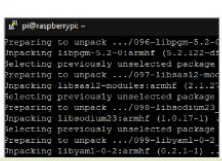
TIP OF THE MONTH



WETRANSFER

There are tons of ways to move files from machine to machine, but transferring them across the cloud is a particularly easy method (as long as your Internet connection is fast enough). WeTransfer (http://wetransfer.com) is a great site for this, with free file transfers of up to 2GB available. You can email files across or create a custom URL that lasts for a week—ideal for temporary sharing.

MAKE – USE – CREATE



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64 Build a DIY Raspberry Pi NAS host

68 Build inside Corsair's leviathan 7000D case

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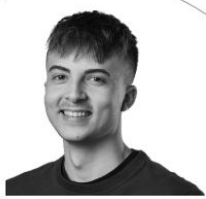


SAM LEWIS
STAFF WRITER

A SMALL HURDLE

I presumed after my first PC build that it would be plain sailing from then on. I couldn't have been more wrong. But that's all part of the fun, right? I challenged myself to put together a Mini-ITX build, as small form factors have always appealed to me. They're just the natural trajectory of technology; well, phones have grown bigger again, but that's not the point.... Anyway, the idea of building a Mini-ITX machine soon had its issues. Besides the fact that everything is much more cramped, some of the parts arrived late (for various reasons beyond anyone's control), and this put a strain on our deadline.

The PC had to be sent to Christian in the photo studio, who thankfully whizzed it all together. However, due to an unfortunate series of events involving unrelated (and unnamed!) individuals, the original NZXT case's glass panel got shattered. Ouch! This changed the whole build. We obviously had to swap the case, resulting in a few other parts being switched around, which Christian had to sort out again. Let's hope things go more smoothly next issue and I can actually complete the build myself! Apart from this blunder, I had no other tech hiccups this month, and hopefully I can keep it that way.

↘ submit your How To project idea to: editor@maximumpc.com

Get Started With Adobe Illustrator

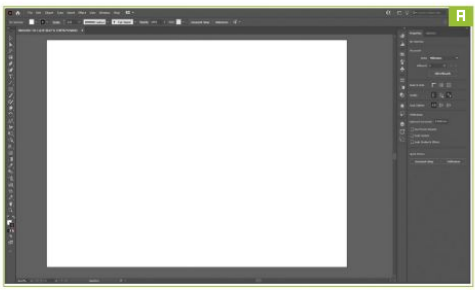
YOU'LL NEED THIS

ADOBE ILLUSTRATOR CC 2020

To view compatibility visit: https://helpx.adobe.com/illustrator/system-requirements.html.

WE'VE RECENTLY FEATURED quite a few Photoshop tutorials, so we thought we'd switch it up a little and give its sister software a bit of love. Illustrator is an equally powerful tool in the Adobe ecosystem. At first glance, all the apps in the Adobe suite look pretty similar. Apart from the names and color schemes, you could easily be forgiven for getting them confused. This, though, is a good play from Adobe; with similar interfaces, it makes switching between the apps a bit easier. We will get on to Illustrator's UI in more detail a little later.

Essentially, the main difference between Photoshop and Illustrator is that Photoshop uses pixels and is raster-based, whereas Illustrator uses vector-based rastering. In simpler terms, vector rastering creates points to make smoother lines. This makes it perfect for creating logos and graphic design work that can be scaled up without pixelation. If you need to create typography work, Illustrator is perfect for that very reason. Nobody wants pixelated text unless you're going for a retro 8-bit look. If you are, then use Photoshop—you'll get it whether you want it or not. Anyway, in this tutorial we're taking a first look at Illustrator, explaining how to navigate around and get started with this excellent tool. –SAM LEWIS



1 CREATE A NEW DOCUMENT

As we mentioned, Illustrator shares a similar interface with Photoshop, and if you've been following our Photoshop tutorials, this should hopefully be a familiar place for you now. The tools aren't identical and certain things are named differently, but the format of the software is the same. When starting up the app, you are greeted by the opening screen, where you can see previous projects and have the option to open or create a new file. For today's tutorial, we are just going to open up a blank A3-sized document. Click the "Create new" button. A window opens and along the top are options for various formats. Head to the "Print" tab and select "A3"—we have chosen a landscape orientation [**Image A**].

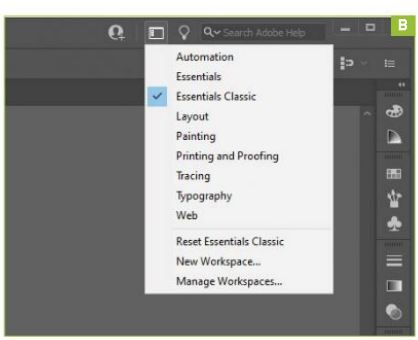
›› A few eagle-eyed readers may notice that when you go from a digital file type, such as a web page template, to a print format, the color mode changes from RGB to CMYK automatically. This is perfectly normal and correct. When we are creating any project for the web or digital media, the color format is always RGB. Digital creations are composed of red, green, and blue color mixes. When it comes to physical artwork, like prints, these are made up of four color combinations—cyan, magenta, yellow, and key (black), to make up the colors you have created.

›› Before we get too technical, we need to click the "Create" button at the bottom-right of this window to create our workspace and get into Illustrator's tools.

2 SET UP YOUR WORKSPACE

The great thing about Adobe software is that the layouts are heavily customizable. If you would like, you can move all the tools around and just keep the ones that you want. There are various presets already created. Toward the top-left of the toolbar, there is a square window icon (for switching workspaces) [**Image B**]. Click this to change the workspace layout to find one that suits your needs. We are using the "Essentials classic" workspace, but we have removed the "Libraries" tab on the right-hand side of the screen, and dragged the "Properties" tab to the bottom of the list next to it, just to make things a little cleaner.

›› On the left of the screen, you have your immediate tools. The main ones include the Selection tool, Direct Selection tool, Lasso tools, Pen tools, and Shape tools. There are lots of tools that make an appearance throughout the Adobe ecosystem, so you may be quite familiar with several of them by now. However, this introduces a potential problem: Certain shortcuts are different, depending on the software you're using. Luckily, you can create custom shortcuts that can be universally used across all of Adobe's programs. This



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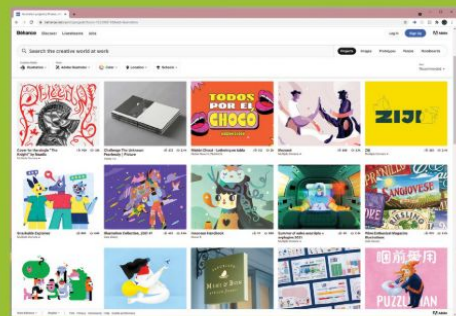
WHY SHOULD YOU USE ILLUSTRATOR?

We briefly touched on some of the uses of Adobe Illustrator earlier, but we have plenty of interesting tutorials lined up to help you get stuck into some imaginative projects in forthcoming issues. We keep comparing it to Photoshop, not necessarily in how similar it is, but how high it sits in the industry hierarchy. Illustrator is the industry standard for creative design work that uses shapes, colors, typography, logos, and so on.

If you are creative and have a talent for art, Illustrator could be a great way for you to step up your skills to create something digitally. It's a great tool for creating artwork exactly how you want it. We aren't disparaging traditional art methods, but if you make a mistake on paper, you can't exactly press Ctrl-Z, can you? With Illustrator, you don't have to worry about making errors and can add to your work as much as you like.

For us, the big appeal of using Illustrator to create digital art is the vector aspect, which in simple terms means that you don't end up with super-jagged edges to your work. The EPS and SVG files that you export from Illustrator can be scaled up as much as you want, and they don't lose any quality. However, if you created the same artwork in Photoshop and zoomed in, it would probably look like something you'd find in *Minecraft*—that should give you a visual idea of the differences between the two. You can also easily pair up a graphics tablet with Illustrator, enabling you to transfer your hand-drawn artwork straight to your PC. If you wanted to sell your digital art, this is a great route to go down, and by using sites such as Adobe's Behance (www.behance.net), you can easily showcase your work online to a very large network of designers.



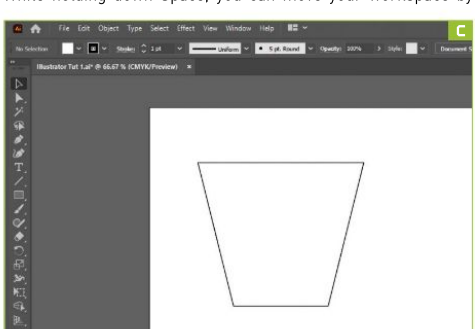
customization control from Adobe is what sets it apart and shows that the company really caters to creatives.

›› On the right-hand side of the screen, we can find some more advanced tools, preferences, and effects. We also have the "Layers" tab, just like Photoshop, plus properties, stroke settings, swatches, and more. As we go through a few different tutorials, we will touch base with more of these.

3 FIND YOUR WAY AROUND

Before we go any further, we need to make sure everything is kept simple and organized. Just like when you've been using Photoshop, things can get messy, and that makes work or personal projects get frustrating, and you may end up wanting to bash a hole through your keyboard. (For the record, do not attempt this—it almost always makes the situation worse.) Save your new document as an AI file with an appropriate name. This is Adobe Illustrator's file type. You can export these documents into many different formats.

›› Navigating around the document is easy enough, too. While holding down Space, you can move your workspace by simultaneously holding down the right button on your mouse and dragging. You can also zoom in and out with the magnifying glass tool on the left toolbar or by pressing Ctrl and the plus and minus keys accordingly. We have already touched on the left-hand and right-hand tools, so we just have the top tabs to look at. The "File" tab is an easy one—it's where all our file information sits; the "New," "Open," "Save," "Print," and "Export" functions are all accessed from here, as well as "Document setup," which is great for changing the file size and information about your project. In the "Edit" tab you can find basic commands such as "Cut," "Copy," "Paste," and so on. You also have color profiles, keyboard shortcuts, and spelling options. The next tab along is where it differs from Photoshop. The "Object" tab has lots of different options to alter something you have created, which is known an object. A Shape or a Pen tool drawing comes under this category and can be altered by the settings in this drop-down menu.



›› The rest of the tabs along the top are fairly generic to Adobe, which makes life a little easier. The "Type" tab contains all the typography settings, as the name implies. The "Select" tab helps you to pick out exactly what you want—it sounds pretty obvious, but trust us when we say this is a lifesaver. The same goes for the appropriately named "Effect," "View," "Window," and "Help" tabs. Thanks, Adobe, for being straight to the point here. Now we've gone over the basics, we are going to create a little vector illustration, starting off with a polygon shape [**Image C**].

4 SHAPING UP

To create this shape, go to the Shape tool on the left-hand side and select the Square tool. Then, using the Direct Selection arrow (the arrow with the white infill), select the bottom-left corner and drag it inward. Do the same on the other side to match. This

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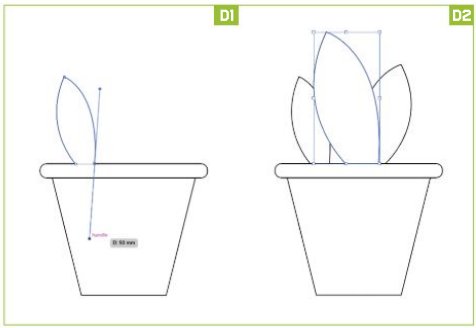
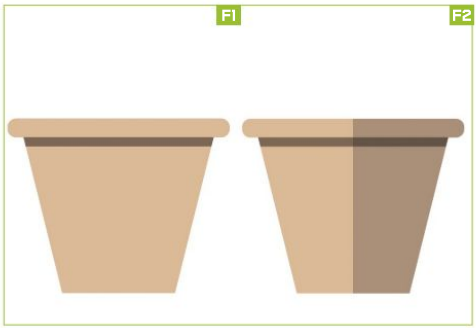


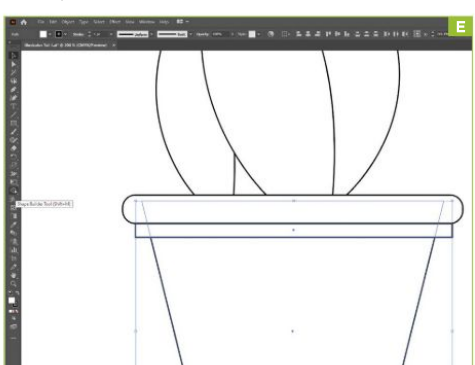


should create a plant pot shape, because we are going to draw a little plant as an introductory tutorial. Next, use the Rounded Rectangle tool to draw a small lip on the top of the plant pot. Click and drag to get the desired shape. Don't worry if it isn't centered, because you can drag this in the middle and it should snap and align to the center point of the pot.

›› Next, we need to start drawing the plants themselves. These are going to be simple curved Pen tool lines, so fear not. Begin by placing one point on the top of the plant pot, then click a point for the top of the plant, and drag a curve [**Image D1**]. Before we connect it to the bottom, hold Alt and click on the top point to end the point there, otherwise you will end up with unwanted lines. As you practice with Pen tool drawing, this will become more obvious. To finish the rest of the leaves [**Image D2**], we duplicated the shapes, and vertically reflected them. This was done using "Transform," by right-clicking the shape.

5 SHADY BUSINESS

To complete this mini drawing, we need to add some color and shading. The style we are after is a form of flat design art, which when made digitally, is usually created using Adobe Illustrator, because it thrives in this area of art. To add shading to the pot, draw another thin rectangle underneath the lip of the pot. When done, use the Selection tool to select the newly drawn shape and the main pot. When these are both highlighted, we need to use Shape Builder tool from the left-hand toolbar (Shift-M). We are using this tool to cut off the edges, so it fits the width of the plant pot perfectly. It should end up looking like the image below [**Image E**].

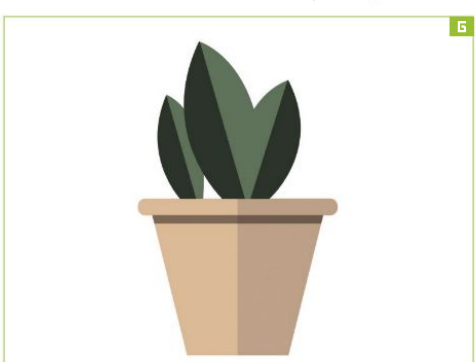


6 COLOR CREATION

Now we need to add some color. We are going to focus on the pot first, choosing an appropriate color. We need to hide the plants, so go to the "Layers" tab and click the eye icon to get rid of these for now. Highlight all sections of the pot and fill them with color. To create the shadow effect, find the rectangle we just created, click in the swatch color, and darken it. The shadow should look like the picture above [**Image F1**].

›› After this, draw another rectangle down the middle of the whole shape and to the side. Again, highlight everything, then subtract the bits of shape around the pot using the Shape Building tool. Turn this new shape black and lower the opacity to around 10%. You should end up with a shaded plant pot [**Image F2**].

›› Now we will focus on the leaves. Make these visible again in the "Layers" tab and hide the plant pot layers instead. Highlight all the leaves and color them in with a nice green. Using the Pen tool, create a shape that cuts halfway through each plant as equally as you can. Then use the Shape Building tool again to cut out a shape that is half of the leaf. Take this half, click into the color swatch, and darken it by choosing a similar but darker tone. Do this for each leaf and, hopefully, you will end up creating a nice little flat design plant artwork like ours [**Image G**]. Keep going through this exercise and try to make it your own by practicing and modifying it however you like. It's a fun way to quickly build up your skills with the Shape, Pen, and Shape Building tools.



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Prepare Your PC for Windows 11

YOU'LL NEED THIS

A PC WITH THE CORRECT CPU
See Step 1 for details.

THERE'S A NEW OS IN TOWN, you can get it for free, and you're going to want it. Windows 11 is a handsome beast, reminiscent of Windows 10, yet still its own thing, with more to recommend it than a centered taskbar and rounded corners on its windows.

Anyone on the Windows Insider Dev Channel will already have had a build of 11 arrive through Windows Update. It is, at the time of writing, quite stable, but is not exactly what you'd call feature-complete. Still, it makes an interesting thing to have in a virtual machine or installed on a spare PC so you can bring it out at parties and impress your friends.

There's a snag, however. It's not yet implemented in the preview build, but Microsoft says this new OS will rely more heavily on hardware security features than any before it. Specifically, we're talking TPM (Trusted Platform Module) 2.0. This can be added to a compatible motherboard with a dongle, or enabled in the BIOS of others. For many self-built PCs, however, it will be a headache. Let's find out about that, and what else you should do before upgrading. –IAN EVENDEN

1 IS YOUR CPU UP TO IT?

Microsoft has published lists of CPUs that are compatible with its latest baby. They're short, but include AMD Ryzens back to the 2XXX series (Zen+, though Microsoft often refers to "Zen 2") and Intel Cores back to eighth-gen (Coffee Lake), plus a handful of Athlons and Celerons unlikely to be of interest to readers of *Maximum PC*. There's a list of Qualcomm chips, too, paving the way for the inevitable takeover of everything by ARM designs (a version of Windows 11 is already running on the Raspberry Pi 4, but currently lacks Wi-Fi functionality). This limited selection of CPUs is probably something to do with their compatibility with the new Windows Driver Model, and if yours is on the list, great. If it isn't, well, Microsoft says it will keep on updating Windows 10 for some time, but you'll miss out on the ability to run Android apps on your PC, the implementation of Direct Storage (a direct link between SSDs and your GPU for faster loading in games) from Xbox-land, and rounded corners on your windows.

2 THE DREADED TPM

Even if your CPU is on the list, it doesn't mean you're completely in the clear. You need a GPU capable of dealing with DirectX 12 (which is most of them) and you need hardware security. No one knows why Microsoft has gone so hard for TPM this time around, but it has, and PC builders are being left to deal with it. There's good news, though: If your motherboard has a TPM socket, you can add it with a $10 dongle [**Image A**]. (As we write, price-gougers are out in force preying on the panic-stricken, but Windows 11 isn't here yet, and more stock will surely arrive.) Many mobos actually have it built in, and you can activate it in the BIOS—which must be UEFI—under "Advanced Mode → Settings → Security Device Support," or something similar [**Image B**]. There's a quick way to check whether yours is activated: Within Windows, open a Run window or hit Win-R, and type `tpm.msc`. The window that opens will give you a quick yes/no answer about whether hardware security is on, and what level it's at [**Image C**]. Remember you need TPM 2.0; the previous 1.2 standard won't cut it. The various mobo makers have been publishing lists of their compatible chipsets, too, so you should be able to find out fairly quickly if you can upgrade, or need to buy a new PC.

WHY, WHY, WHY?

Microsoft is being tight-lipped about why it has restricted Windows 11 to CPUs made in the past four years or so, but it probably comes down to two things. Windows 11 PCs are meant to be secure. Very secure, with TPM 2.0 and virtualization-based security, which isolates a region of memory for Windows to operate its security solutions in, so they can't be accessed even through an OS vulnerability.

MS also doesn't want Windows 11 PCs to crash, and one of the most common causes of crashes is a bad driver. The concept of Driver Package Isolation is not new, but we can expect to see much more of it in Windows 11. It means drivers run from a centralized Driver Store rather than System32, can only write data to system-mandated areas, and can only interact with other drivers using system-supplied functions or interfaces.

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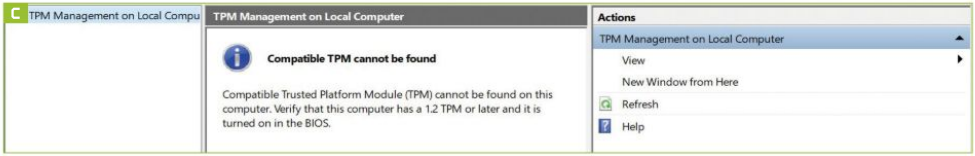
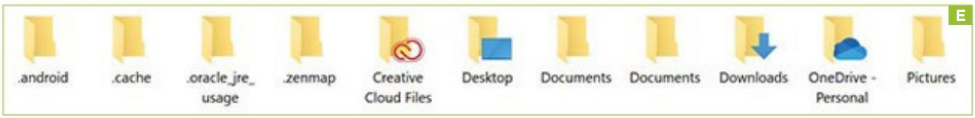

C
TPM Management on Local Compu
TPM Management on Local Computer
Compatible TPM cannot be found
Compatible Trusted Platform Module (TPM) cannot be found on this computer. Verify that this computer has a 1.2 TPM or later and it is turned on in the BIOS.
Actions
TPM Management on Local Computer
View
New Window from Here
Refresh
Help



3 HEALTH CHECK

Once upon a time, Microsoft released a little app called PC Health Check that claimed to tell you if your PC was ready for Windows 11. It did this, but in an enragingly vague way that didn't actually tell you why your pride and joy had failed the test. As we write, Microsoft has withdrawn the app, but its replacement has yet to appear. We await more detailed information about our PC's failings with bated breath.

4 A FEW OTHER BITS

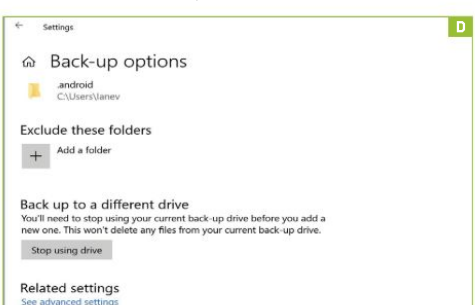
Got 4GB of RAM? How about 64GB of storage? Screen greater than 720p? You're all set. The minimum requirements for Windows 11 just happen to be the same as those for Microsoft Office and Teams, making it look like MS is going for some sort of synergistic joined-up experience.

5 GETTING READY FOR AN UPGRADE

Windows 11 is similar enough to Windows 10 that we expect an in-place upgrade will be possible, keeping all your documents, and possibly all your installed apps, where you left them. The way it was rolled out to Dev Channel users supports this—it appeared in Windows Update in exactly the same way a new version of Windows 10 would. Getting a new OS, however, can be an opportunity for a few other upgrades, and a new, fast, SSD boot drive wouldn't be out of place to make Windows 11 feel even more responsive. Especially now the prices of PCIe Gen 4 models have fallen to levels normal humans can afford.

6 SERIAL NUMBERS

Reinstalling all your apps is a pain, but it goes far more smoothly if you've got your serial numbers backed up. This goes for Windows itself—we don't know what the punishment will be for running an unactivated build of Windows 11, but it's not outside the realms of possibility that it will be harsher than just not being able to change your desktop background. If you've used your Microsoft account for activation, it might just be a case of logging in and selecting the serial number you want to transfer. We won't know until the retail build is here. Adobe apps let you manage installations from the Adobe account management website, so you can deactivate your old Win 10 PC and activate the new Win 11 one, though you can have a CC subscription on two PCs at once with no penalty.

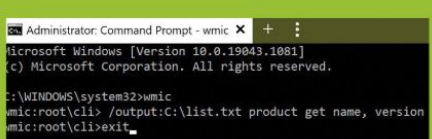

D
Settings
Back-up options
.android
C:\Users\lanev
Exclude these folders
Add a folder
Back up to a different drive
You'll need to stop using your current back-up drive before you add a new one. This won't delete any files from your current back-up drive.
Stop using drive
Related settings
See advanced settings

© MICROSOFT

7 BACKUPS

You are already backing your documents up, aren't you? Cloud storage systems such as OneDrive and Google Drive make it easy to keep a rolling off-site backup of your documents, while Windows' own File History will do the job if you prefer an external hard drive or NAS. File History even restores the latest versions of your files to their original locations on your hard drive if you select "Settings → Backup settings → More options → Restore files from a current backup" [**Image D**]. Why this isn't just called "File History" is beyond us, as it makes searching for the settings far more difficult, but perhaps Win 11 can fix this. You're shown your backed-up folders as they are on your backup drive, and you can restore them all or a folder at a time [**Image E**].

LIST INSTALLED APPS



If you decide to go with a clean installation of Windows 11, you'll need to reinstall all your apps, and it can be useful to see exactly what you've got installed on your PC, especially if it's been a while since you set it up.

To do this, run Command Prompt as an administrator, and type `wmic` and Enter. Once the WMIC prompt opens, type `/output:C:\list.txt product get name, version` then hit Enter. You can replace `C:\list.txt` with another file name or output directory. Close the WMIC window once it's finished. A list of your installed software should be available as a text file in the location you provided for the output file. You also get a version number, so you can check whether updates are available when it comes to doing the reinstall.

Build a DIY Raspberry Pi NAS

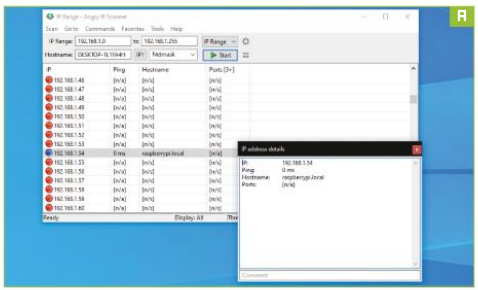
YOU'LL NEED THIS

A RASPBERRY PI
Fourth generation is best; plus you need a USB hard drive.

RASPBERRY PI OS LITE
Download from http://raspberrypi.org/software/operating-systems/.

ETCHER
Download from www.balena.io/etcher/.

LET'S BEGIN WITH THE BAD NEWS, before you get all excited: The Raspberry Pi 4 is not the best choice as a NAS host. What is more, the Pis that came before it should probably be avoided at all costs. This isn't some elitist sentiment, it's a hardware issue. The earliest Pis top out at USB 2.0, have a limited controller that leans heavily on CPU power, and give their USB ports and Ethernet connection a shared bus, severely limiting bandwidth. The Pi 4 is built in a more sensible way, but it still shares each of its USB ports over a single PCIe lane with 4Gb/s bandwidth. If speed is your concern, look elsewhere. However, if an ultra-budget NAS (with room to tinker on top) sounds good, you're in the right place. It's certainly a clever way to put an unused Raspberry Pi to good use, and OpenMediaVault makes file sharing far easier than it would be in raw unfettered Linux. If you're lucky enough to have an old PC kicking around, this is even more applicable, particularly because you'll be able to use SATA-connected drives to set up a RAID configuration, something that isn't available here—just install it on top of Debian instead of Raspberry Pi OS. –ALEX COX



1 LET THERE BE RASPBERRY PI OS LITE

We'll spare you the usual long-winded explanation on how to install an OS on to your Raspberry Pi because it's pretty self-explanatory; try Etcher or Win32DiskImager to get that card written, and while both tools should automatically eliminate any critical drives, do your own due diligence to make sure you're not overwriting anything important. Although it would be nice to run OpenMediaVault inside a Docker container, that's apparently not possible due to it getting its claws into so many of Linux's services—you need to put it as close to bare metal as you can, so we're going to use Raspberry Pi OS Lite as our base. Grab the latest version and write it to a microSD card. When it's done you'll see a "boot" partition mounted on your Windows machine; make a new (empty) text file here and name it "ssh"—this will enable us to access the Linux shell remotely.

2 IP FROM PI

Put the card in your Pi, hook it up to an Ethernet connection, and power up. Give it a few minutes to get up to speed, then let's find the IP address of the Pi, and do so by cheating: Download Angry IP Scanner from http://angryip.org, run it, and search in the usual range your router dishes out—in our case, we need to look for 192.168.1.0 to 192.168.1.255. Run the scan [**Image A**], find your Pi's hostname, and note down its IP address.

3 OPEN THE VAULT

Time to log in. We'll use the stone-cold classic PuTTY as an SSH client, though many versions of Windows now include a command-line SSH tool by default—this will do the job just as well. Enter the IP address you just noted down, and ensure you're connecting to port 22 using SSH. The first time you connect, you need to accept the fingerprint of your Pi; this is fine to do, since you're connecting to a local machine. Now enter the login details—by default Raspbian uses the "pi" user, with the password "raspberry." Immediately change that password by typing `passwd` and following the prompts. Now let's install OpenMediaVault. Start by ensuring the packages on your Pi are up to date by running `sudo apt update` followed by `sudo apt upgrade`,

MAKE MEDIA MARVELOUS

OpenMediaVault is darned strong at hosting your media, although it doesn't do much more than act as a file server by default. To extend its capabilities, you need to install plugins that cover those network services you want to use. Check the "Plugins" menu in the sidebar to see the kind of thing you can add—it's a vast list, so zero in on the "Multimedia" section if you're interested in streaming. Probably your first port of call should be openmediavault-minidlna, which can serve files over DLNA/UPnP-AV, a protocol many clients (smart TVs, Kodi, et al) are happy to work with. It's not the easiest, and you'll need to tinker with a text file to get it working, but it's worth the install. If you're into music, OMV can be extended with shairport (which makes it pretend to be an Airport Express) and forked-daapd, which gives it Digital Audio Access Protocol capabilities.

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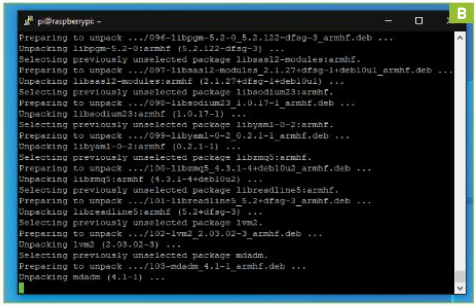

B
pi@raspberrypi: ~
Preparing to unpack .../096-libpgm-5.2-0_5.2.122~dfsg-3_armhf.deb ...
Unpacking libpgm-5.2-0:armhf (5.2.122~dfsg-3) ...
Selecting previously unselected package libasn12-modules:armhf.
Preparing to unpack .../097-libasn12-modules_2.1.27+dfsg-1+deb10u1_armhf.deb ...
Unpacking libasn12-modules:armhf (2.1.27+dfsg-1+deb10u1) ...
Selecting previously unselected package libsodium23:armhf.
Preparing to unpack .../098-libsodium23_1.0.17-1_armhf.deb ...
Unpacking libsodium23:armhf (1.0.17-1) ...
Selecting previously unselected package libyaml-0-2:armhf.
Preparing to unpack .../099-libyaml-0-2_0.2.1-1_armhf.deb ...
Unpacking libyaml-0-2:armhf (0.2.1-1) ...
Selecting previously unselected package libzmq5:armhf.
Preparing to unpack .../100-libzmq5_4.3.1-4+deb10u2_armhf.deb ...
Unpacking libzmq5:armhf (4.3.1-4+deb10u2) ...
Selecting previously unselected package libreadline5:armhf.
Preparing to unpack .../101-libreadline5_5.2+dfsg-3_armhf.deb ...
Unpacking libreadline5:armhf (5.2+dfsg-3) ...
Selecting previously unselected package lvm2.
Preparing to unpack .../102-lvm2_2.03.02-3_armhf.deb ...
Unpacking lvm2 (2.03.02-3) ...
Selecting previously unselected package mdadm.
Preparing to unpack .../103-mdadm_4.1-1_armhf.deb ...
Unpacking mdadm (4.1-1) ...

then run the following command to download and execute a script written by OMV's developers [Image B] to get it installed:

```
sudo wget -O - https://github.com/OpenMediaVault-Plugin-Developers/installScript/raw/master/install | sudo bash
```

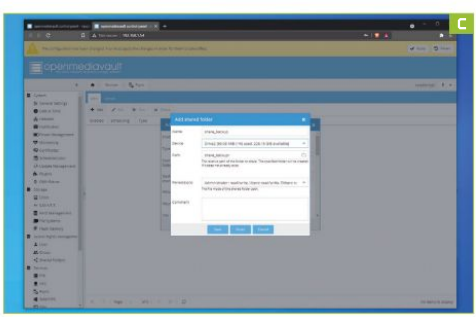
›› This will take its sweet time, even on a Raspberry Pi 4. Once it's done it'll likely kick you out of your SSH connection, because OMV will have jiggled some settings about. That's OK, because we're done with SSH for now—open a web browser and point it to your Raspberry Pi's IP address, and you'll see OMV's web UI. Log in with the username "admin" and password "openmediavault."

4 DRIVE TIME

Let's quickly change another password by heading to "General Settings → Web Administrator password," entering your new password, and clicking "Save." Log in again with your new credentials, then plug your drive(s) into the Raspberry Pi—preferably through a powered USB hub, which will increase stability. Head to the disks section in the left-hand column, and you should see any drives you've hooked up listed below your Pi's internal storage. For each one, click it and select "Wipe"—unless you're attempting to destroy something particularly incriminating, a quick wipe suffices. Now let's give those drives a file structure to work with by heading to the "File Systems" section, clicking "Create," selecting your drive, giving it a label, then clicking "OK." The default EXT4 file system will be fine, but feel free to change it if you want to experiment.

5 SHARING IS CARING

Creating the filesystem is just the start. With our drives ready, they can be mounted with the appropriate button on the "File Systems" screen. Now we can set them up as SMB/CIFS shares by heading to the appropriate section, going to the "Shares" tab, and clicking "Add." Click the plus symbol to set up



DO MORE VIA DOCKER

You can't run OMV on Docker, but you can run Docker on top of OMV. Head to "OMV-Extras," open the "Docker" tab, click the "Docker" button, and select "Install," then do the same with Portainer, which helps you monitor and manage Docker, and (optionally) Yacht, a similar container management tool. Click the button to open Portainer and set up your admin account. Click "Docker," then "Connect," then head to "App Templates." There's a lot to Portainer—far more than we can fit here—but click "httpd" and then "Deploy the container" for a quick demo: In two clicks, you've stood up a web server that can be accessed via <ip address>:49153. With a little elbow grease, you can run things like Plex on your Pi; and you don't have to use Portainer, as Docker and Docker Compose are now available if you SSH into your Pi.

a new shared folder, give it a name, select which drive it should be on, and type a folder name into the path box. This will be our shared folder for anyone on the network, so change the permissions to "Everyone: read/write," then hit "Save." Change the "Public" setting in the "Add share" window to "Only guests" so nobody requires any credentials to access the folder, then click "Save." Now head back to the "SMB/CIFS" section, flip the switch at the top to toggle the function on, click "Save," and apply the new configuration. You can now connect to your shared drive; your Pi will show up in Windows Explorer's "Network" section, with the shared folder inside. Use the username "guest" with no password to gain access.

6 MIRROR, MIRROR...

Some bad news, here, to close us out: We can't use RAID on a Raspberry Pi, because OMV does not support it over USB. That's annoying but fair—USB is not exactly a rock-solid way to do it—but we can at least use multiple drives, and ask OMV to create an automatic backup for us. To mirror, say, the "share" folder we created earlier, head to "Rsync" in the left column, click "Add" to create a new job, select your old folder as the source, and create a new one (using the plus sign) on your second drive [Image C] to use as the destination. If you want to synchronize the folders once an hour, flip the "Every N minute" switch. We also recommend flipping on the "Delete" option, so that files removed from the main folder are also removed from the backup to stop it filling up. Hit "Save," apply the changes on the yellow bar at the top, then (after dropping a few files on your server) click the "Run" button to test out the transfer.

Play Old DOS Games on Raspberry Pi

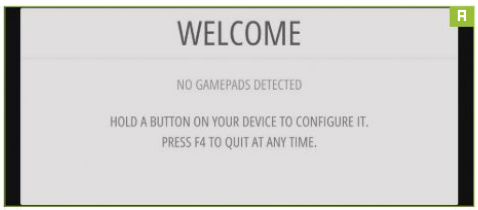
YOU'LL NEED THIS

RASPBERRY PI 4/400
Plus a microSD card or other compatible storage, a game controller, and some games you already own.

THOSE OLD DOS GAMES gathering dust in a cupboard can be given a new lease of life through an emulator, but why stop there? Why not build a retrogaming box that's got wireless controller support, connects to your TV through HDMI, and leaves your PC free to do other things?

You can do just this with a Raspberry Pi. There's a whole operating system, RetroPie, dedicated to the playing of retro games, and while emulating consoles means skirting around the edge of the law, playing the DOS games you already own is much more legally pleasing, and there's the bonus of several very good games being made available as freeware, too.

Installing RetroPie is the same as any other Raspberry Pi operating system—you can let the Raspberry Pi Imager app take the strain. All you'll need is a blank microSD card, or a USB SSD if you've updated your Pi's bootloader to boot from USB. Doing this can decrease loading times and make your Pi more responsive, but it's not really necessary for this project because the Pi's loading times from microSD are already far ahead of the machines that DOS games originally ran on. –IAN EVENDEN



1 GET RETROPIE

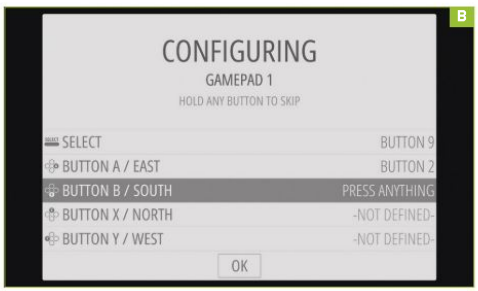
The Raspberry Pi Imager (www.raspberrypi.org/software) is a useful tool. It will format a memory card as FAT32 when Windows won't but it's really for use with a Raspberry Pi. You can choose your build of RetroPie from the Imager, under "Choose OS → Emulation and game OS → RetroPie," where you'll find versions for different boards, or you can download an image from https://retropie.org.uk/download/—again choose the right one for your hardware—and install it from "Choose OS → Use custom in the Imager." Insert a microSD card you don't mind erasing into your PC's card reader, and let the Imager do its thing.

2 INITIAL SETUP

Insert the microSD you've prepared into your Pi, make sure no other bootable drives are attached, and throw the power switch. RetroPie is Linux with a controller-friendly skin on top and a bunch of console emulators pre-installed, so as it boots you'll see a load of scrolling text on the screen. Eventually, you're prompted to get a controller set up [Image A], unless you want to use a mouse and keyboard. Wired peripherals are the easiest to use—just plug them in. If you want to play point and click games, you're going to want a mouse. If you've got a PlayStation 4 or 5 controller, you can connect this to the Pi with a USB cable and use it, setting up Bluetooth later to use it wirelessly. Otherwise, connect a keyboard (a wireless dongle is fine) to one of the Pi's USB ports and set up controller inputs using its keys [Image B]. RetroPie uses the East face button (the circle on a PlayStation pad; B on Xbox) as commit, and the South button (cross on PlayStation; A on Xbox) as cancel.

3 WIRELESSNESS

You'll want to connect the Pi to your wireless network. The RetroPie background screen is actually a button, and pressing it opens the config menu [Image C]. From here, you can connect Wi-Fi and Bluetooth. Wi-Fi is at the bottom. Choose it, and you may get an error message that your location isn't set. Launch the Configuration Tool when prompted, and prepare to peer closely at your screen (and attach a keyboard). The



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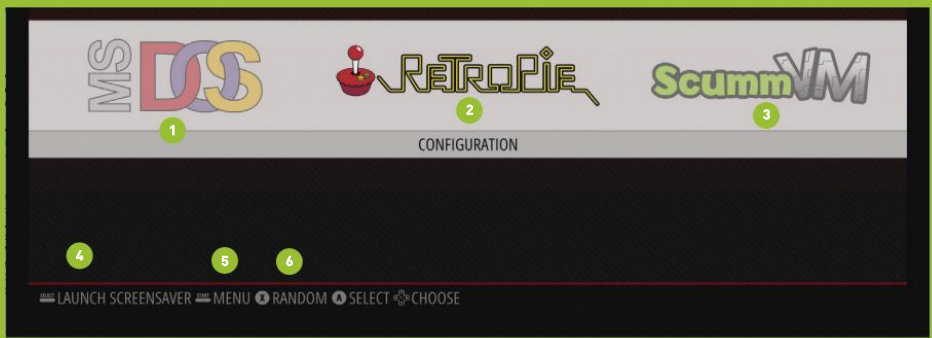
THE RETROPIE INTERFACE



1. MS-DOS LOGO
Opens DOSBox games list. You can scroll across to discover more systems.

2. RETROPIE LOGO
Opens the configuration menu.

3. SCUMMVM LOGO
Opens Scumm games list and allows ScummVM to be opened for configuration.

4. SCREENSAVER
Dims the screen, or plays a movie file in the "Screensaver" folder.

5. MENU
Opens the main menu.

6. RANDOM
Plays a random game.

Location tool is a tiny box in the center, and the US is a long way down the list. Choose your location, press "Finish," and the Pi reboots. Get back into the config menu and choose "Wi-Fi" again. You'll get another tiny menu, but this one allows you to connect: Choose your network, input the password. Press "Exit" to leave.

›› To connect a Bluetooth controller, select "Bluetooth" from the list, and you're back in tiny menu world. Put your controller into pairing mode, and use your keyboard to tell the Pi to search for Bluetooth devices. After what seems almost too long, a list of local Bluetooth devices will appear. Choose your controller, follow the instructions, it should work.

4 DOSBOX

To play DOS games, you need to install DOSBox. Open the config menu and select "RetroPie Setup." Choose "Manage Packages → Manage Optional Packages → Dosbox," then "Install from Source → Yes." RetroPie then contacts the repository and does the rest itself with a screen full of scrolling text. Now do the same for ScummVM, which takes ages. Restart.

5 TRANSFER GAMES

An emulation station is no good without games, and there's a couple of ways to get your ROMs on to it. The easiest is over the network. RetroPie presents itself on your local network as a Samba share when connected to the Wi-Fi, so open a new Explorer window on your PC, and type `\\retropie` in the address bar. It should pop up with a list of folders. Open "Roms" and add two new folders: "PC" and "PCdata." Within "PCdata," add new folders for your games, but keep their names under eight characters, as this is all DOS supports. Then copy the files over. You may need to add more folders, for example "ScummVM." With your legal console ROMs, you can then drop them into the appropriate system folder.

›› The other way to get games on to the Pi is to use a USB drive. You need to format it as FAT32, so use the Imager if Windows isn't being helpful. Create a folder on the stick called "retropie" and plug it into the Pi. Wait. If the stick has an activity light, wait until it has stopped flashing. If not, guess. Remove the stick, and plug it into your PC. The Pi will have added some folders, so copy your games to the appropriate folder—create "PC" and "PCdata" if needed —and plug it back into the Pi. Wait again as it copies all the files off the stick. Many DOSBox games require a script file in the "PC" folder to configure DOS every time it runs—see the boxout below. Remove the stick, restart the Pi, and your games should now show up in the interface.

6 PLAYING

To actually play one of the games, just select the name of the host system from RetroPie's main menu, then choose a game from the list.

SHELL SCRIPTS

Text files with the extension .sh, shell scripts sit in the "Roms/PC" folder and tell DOSBox what to do. Here's an example one for *Command & Conquer*, which we've shortened to "CC."

```
#!/bin/bash
/opt/retropie/emulators/dosbox/bin/dosbox -c "mount c
~RetroPie/roms/PCdata" -c "c:" -c "cd CC" -c "c&c.exe" -c "exit"
```

Let's take that apart. The first line opens Bash, a shell into which you can enter commands. The second line launches DOSBox (change it to wherever you've installed it, if you've deviated from the default), and then is full of "-c"s, which separate DOSBox commands. First you mount the "PCdata" folder as a drive, then change into the "CC" directory, then launch the executable. The "exit" command is there for when you've finished playing, and want to exit to the RetroPie interface rather than turning the system off.

© RETROPIE PROJECT

BUILD IT

CHRISTIAN GUYTON, STAFF WRITER

Bigger is Better

Corsair is kicking off with new large-scale hardware, so let's see how it builds...

LENGTH OF TIME: **1-2 HOURS** | LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

FULL-TOWER MACHINES can be a point of contention for system-builders everywhere. It's not because they're difficult to build (unless you consider lugging a 40-pound case around difficult, in which case, well, fair enough), nor is it because they cost more; it makes sense that more metal and glass is going to end up increasing the price. Generally, the debate boils down to whether or not such chunky PCs are actually necessary, especially given the wealth of excellent mid-tower systems available.

Corsair clearly isn't familiar with such arguments, because the California-based manufacturer has just unveiled one of its biggest cases yet, paired with a beefy new AIO cooler with a 420mm radiator—the company's first. The Corsair 7000D Airflow is a seriously big case, designed with the aforementioned Capellix AIO in mind, so we're putting Corsair's new components to the test with a large-scale system build.

What's the target spec here, you ask? Well, it's essentially just a powerhouse PC; whether it's used as a monster gaming rig or a workstation system is down to you. We'll break down some of the potential uses of this case and cooler later on (and you can check out our full review of the 7000D Airflow in this very issue, on pg. 84), but for now we're just looking to assemble a powerful full-tower machine with the latest and greatest of PC hardware.

We'll be going a bit more in-depth in our conclusion after assembling this system, because we want to delve properly into the thermal performance of the build. Will Corsair's shiny new case live up to its name and deliver top-notch airflow to keep our system cool? Let's find out.

ON THE CASE

WE'VE ALREADY MENTIONED the case and cooler, but let's get into details. The Corsair 7000D Airflow is a gigantic construction of steel and tempered glass that offers everything from EATX support to numerous drive mounts, with triangular perforation on the top, front, and right-hand panels to ensure superior airflow from any of the four radiator mounts. Meanwhile, the iCUE H170i Elite Capellix AIO cooler offers supposedly top-tier CPU cooling with 57 addressable RGB LEDs (33 on the pump block, and eight per 140mm fan) to ensure your PC looks fly as heck.

For our processor, we've got the almighty Ryzen 9 5950X from AMD, a 32-thread powerhouse with a boost clock of up to 4.9GHz. Overclocking in this system should be a breeze with our AIO cooler, which is good since the 7nm 5950X is capable of producing a lot of heat. It's paired with a SUPRIM graphics card from MSI, within which nestles Nvidia's spicy new RTX 3070 Ti GPU.

Our motherboard is the Asus ROG Crosshair VIII Dark Hero, an X570-chipset ATX mobo packed with features. From on-board Wi-Fi to chunky SSD heat shields and RGB lighting, it makes for a striking centerpiece. We also have a 1TB Gigabyte Aorus Gen4 M.2 SSD, and two sticks of Corsair Vengeance RGB Pro SL RAM, offering 8GB per stick at 3,200MHz, with a CAS latency of 16.

We promise that's the last piece of Corsair hardware going into this build. The Pro SL memory is sleek and fast, perfectly matching the rest of our hardware with its bright RGB lighting.

For additional storage, we've got a 12TB Seagate Barracuda Pro hard drive, which is overkill, but guarantees we've got enough space. Lastly, it's all powered by EVGA's new 650W SuperNOVA G6, a reliable PSU from one of our favorite manufacturers.

INGREDIENTS

PART		STREET PRICE
Case	Corsair 7000D Airflow	$260
Motherboard	Asus ROG Crosshair VIII Dark Hero	$383
CPU	AMD Ryzen 9 5950X	$890
CPU Cooler	Corsair iCUE H170i Elite Capellix AIO	$230
Memory	16GB (2x 8GB) Corsair Vengeance RGB Pro SL DDR4-3200	$105
GPU	MSI GeForce RTX 3070 Ti SUPRIM X 8G	$600/ $1,420
PSU	650W EVGA SuperNOVA G6	$150
SSD	1TB Gigabyte Aorus Gen4 M.2 NVMe SSD	$170
HDD	12TB Seagate Barracuda Pro HDD	$270
OS	Windows 10 Home 64-bit OEM	$32
Total		$3,090/ $3,910

1 DOUBLE DOORS

STRIPPING DOWN the 7000D Airflow is straightforward enough, but there's a lot to remove, so we'll split it into two steps. First remove the single screw from each hinge on the two side panels, then open them and lift the panels off their hinges, being extra careful with that big glass window. Behind the metal side panel, a second metal door is secured via a hinge and magnets; remove this, too. The perforated front and top panels only require a little force to remove, fitting in place via push-pins. Beneath these, you'll find magnetic dust filters that can be lifted off easily. Keep the 7000D's box and packaging nearby to store these parts until the build is complete.

2 EXCISE EXTRAS

THE 7000D is exceptionally well equipped, but there are plenty of internal tools that we won't require for this build. First up, you can remove all of the extraneous SSD mounts behind the mobo, along with the HDD drive cage that sits closest to the PSU slot. You can take out two of the remaining HDD trays, too, but we've left them in place for any future hard drive additions. Next, remove the two radiator mounting brackets, one from the top with thumbscrews and one from the side with a screwdriver. Lastly, unscrew and remove the smaller metal strip section from the cable blanking plate, as this will get in the way later due to our chunky power cables.

3 PROCESSING POINTS

ANOTHER AMD BUILD, another quick and easy CPU installation. This couldn't be more straightforward; lift the metal retention arm from the side of the CPU socket until it stands vertically, drop the chip into place (making sure to line up the gold triangle with the triangle on the socket), then lower the arm back into position. Just be careful when handling Ryzen processors, as their pins are delicate and far too easy to bend or snap. Unlike most Ryzen CPUs, the 5950X doesn't come with one of AMD's Wraith coolers, which is a good thing here as it means the stock cooler won't go to waste. The 5950X is available bundled with a variety of AIO coolers, should you opt for a different cooling solution from the Corsair Capellix.

4 MEMORY MATTERS

NEXT UP IS OUR MEMORY. 16GB might feel like a fairly standard RAM capacity for a beefy build like this, but it's perfectly sufficient for our needs; should you plan on using this system for any memory-intensive tasks, upgrading to a 32GB or even 64GB kit is always an option in the future. To install the memory, all you need to do is release the clasps on the DIMM slots (the appropriate two prioritized slots to use are marked on the motherboard itself), and lower the memory into place, giving it a gentle push down until each stick clicks into place. Job done, on to the next step.

7 RADIATOR READY

PREPPING THE CAPELLIX RADIATOR is our next step. To do this, we recommend first situating the radiator within the case so the tubing sits behind the front panel, to best understand the overall alignment of the cooler and fans. Install the fans using the included long screws, making sure that the fan cables will be positioned at the back of the motherboard cavity for easier cable management (you can leave these cables bundled up for now). Once the fans are in place, screw the opposing side of the radiator on to the upper mounting bracket you removed from the case roof earlier. Since this will be dropped into the case later on and secured with thumbscrews, you can leave yourself a bit of room to work and set this assembly aside for now.

8 MOTHERBOARD MOUNTING

IT'S TIME TO SITUATE our motherboard (and its assembled components) inside the case. The 7000D is nothing if not roomy, so this should be quick and easy. Place the case on its side and lower the motherboard into position carefully, aligning the rear I/O with the slot before using the provided screws to secure it to the stand-offs, first at the four corners and then along the four sides. If you're not sure which screws to use (the 7000D comes with a lot of them), you're looking for small black screws with a flat rim; to check, try screwing one into a stand-off with your fingers before installing the mobo. If it screws in smoothly and can't just be pulled out, you've got the right ones. Remember not to over-tighten these screws, as they can cause the mobo to warp.

5 SHIELDS SET

WE'LL BE INSTALLING our SSD underneath the smaller heat shield marked with the reflective "Dark Hero" typography. You'll need a small screwdriver to remove this; once it's out of the way, make sure that the stand-off underneath is in the correct position, then insert the Gigabyte M.2 drive into the slot at a 30-degree angle, and push it down until it aligns with the top of the stand-off. You don't need any additional M.2 screws here; the built-in screw that secures the heat shield will also secure the SSD. Don't forget to remove the plastic cover on the sticky thermal pad on the underside of the heat shield before returning it to the slot and screwing it down.

6 PUMP PREP

THE CAPELLIX AIO COOLER comes with a pre-installed Intel CPU bracket, which you need to remove before continuing. Be careful with this, as a layer of thermal paste comes applied on the underside of the pump, and you don't want to get this all over your fingers. We'll be replacing this Intel bracket with the included AM4 bracket as per the Capellix's instructions; this is fairly easy, as the brackets simply slot on to either side of the pump block before the mounting clasps are fitted using thumbscrews. The Dark Hero mobo should come with a stock AM4 bracket fitted; if it doesn't, you need to install this, too. At this stage, you can swap the black plastic frontplate of the pump unit for a white one, which will result in a brighter RGB effect from the pump's 33 LEDs.

9 GET GRAPHICAL

THIS IS ONE BIG and heavy graphics card; so heavy that it comes with an adjustable stand. For now, keep the case on its side and remove the two blanking plates for the PCIe slot on the mobo closest to the processor. Open the clasp on that slot and carefully lower the GPU into place, pushing it down until it clicks. Use the two screws from the blanking plates to secure it. Turn the case upright again; you'll notice that the card sags slightly due to its weight. Position the stand below the unsecured end of the GPU, and extend it until it supports the card horizontally, avoiding the fans, then use the thumbscrew to secure it. Be careful when moving the case from here on in; we found the stand susceptible to falling out of position.

10 POWER PLACEMENT

INSTALLING THE POWER SUPPLY is typically one of the easiest parts of a build, especially in a spacious full-tower case. Pre-install your power cables to prevent rummaging around under the PSU shroud later; you'll need cables for the motherboard ATX, dual VGA, SATA/accessories, and one CPU power cable. If you want to overclock your processor, you'll want to use a second CPU cable to plug into the four-pin connector on the mobo, although you may want to spring for a higher-wattage PSU in that case—650W is suitable for this system, but a higher-capacity PSU allows more headroom for future upgrades, too. Once all the cables are clipped in place, position the PSU at the rear of the case, and secure it with four screws.

11 COOLER CONNECTION

WITH MANY OF OUR PARTS IN PLACE, it's time to install the AIO cooler we prepped earlier. Fitting the radiator should be simple; lower it into place until the mounting bracket sits in its original position, making sure the cabling is at the front of the case and the pump doesn't hit anything. If it doesn't quite fit, you may need to slightly loosen the screws holding the radiator to the bracket and slide it along the bracket until it can be dropped into place. Secure the bracket at both ends with the thumbscrews, then position the pump block over the CPU. The metal clasps we installed earlier should loop over the plastic "hook" on either side of the CPU socket; once in place, fasten the thumbscrews first with your fingers, then with a screwdriver (again, be sure not to over-tighten these).

12 HUB HUBBUB

BEFORE WE INSTALL the fan/RGB hub that comes with the Corsair AIO, the pre-installed compact fan hub inside the 7000D needs to be unplugged and removed via the three screws that hold it in place. Our new hub won't go in the same position; use the 3M sticky pads to secure it near the top of the remaining cable blanking plate, as shown. Once in position, plug in all the fan power and RGB cables, as well as the connector from the AIO pump. Use the Velcro strips and cable routing paths to organize these as best you can, as it'll make your final cable management steps easier. One of the case fans will have a four-pin extender attached to its cable; you can remove this, as the new hub's position doesn't demand it, and it'll just create more cable slack to worry about otherwise.

13 DRIVE DEALING

THE LAST COMPONENT WE'RE ADDING is the hard drive. Corsair hasn't reinvented the wheel with these drive trays, but that's a good thing; the flexible plastic lets you snap the HDD into place easily, then the tray slots back on to its rails inside the drive cage, and clicks to secure. Plug the SATA power cables from the PSU into both the HDD and the fan hub, then run a SATA connector cable (one should be included with the motherboard) from the drive to any one of the SATA ports on the mobo. These can be a little tricky to reach as they are hidden beneath the end of the GPU, but it doesn't matter which port you use since the M.2 SSD will be our boot drive anyway.

14 FINISHING FLOURISH

OUR LAST STEP is to plug in all the stray cables from our PSU and front I/O. This is fairly self-explanatory; just match each cable to the relevant header on the mobo, routing them through the case as you go. Use cable ties and the included Velcro strips to secure the cables in neat bundles, ready to be concealed. Make sure there aren't any protruding cables behind the mobo plate, as this will make re-installing the metal secondary panel tricky (the magnets that secure it aren't that strong). Put the dust filters and metal panels back on the case, with the glass window going on last. Return the screws to the door hinges, and you're all wrapped up. Time to test this beast.

1 **Corsair's case and cooler fans look brilliant and also run quietly; the loudest part of this build is the HDD.**

2 **You can use Corsair's iCUE software to customize the appearance of the RGB components, including the fans, memory, and pump block.**

3 **This little window is handy if you want to use a pricier PSU with an integrated display.**

CONCLUDING THOUGHTS

WE'D LOVE TO SAY that the 7000D offers excellent airflow and heat management... So we will, because it does. Component temperatures sat in the low 30s while the system was idling or running low-intensity programs (such as Microsoft Word), and even thrashing the build for over half an hour with Prime95's torture test didn't see the CPU rise above 70 C. Mainboard temps remained low, with noticeably good airflow within the case.

The Corsair AIO worked efficiently and quietly, with some excellent lighting effects. The case and GPU fans were similarly gentle. The only part of the system that became notably warm during testing was the RTX 3070 Ti, the metal backplate of which grew quite hot during heavy graphical benchmarks. Core GPU temperatures didn't rise above 65 C, though.

Thermals aside, the GPU performed on target. 4K gaming is an option, although most games will dip below 60fps at higher graphical settings. 1440p and 1080p gaming are a breeze, and the 3070 Ti also handled ray-tracing tests well, achieving 8,986 in 3DMark's Port Royal benchmark, although activating ray-traced effects will still cause a significant frame rate drop in games.

The Ryzen 9 5950X also offered stellar performance, boosting frame rates in processor-bound games such as *Total War: Warhammer II*, and easily handling CPU benchmark tests without significant temperature spikes. The Gigabyte Aorus Gen4 SSD is a beast, outpacing most PCIe 4.0 SSDs with read and write speeds over 4GB/s.

We did have some difficulties when first booting this machine, though. Use of the RGB/fan hub that comes with the Capellix cooler meant we had to do some BIOS tweaking to get this build to boot without a CPU fan error. Disabling the automatic QFAN control in the BIOS and swapping the three-pin pump power connector from the AIO_PUMP to the CPU_FAN header fixed the problem, oddly.

We ran a standard CrystalDisk speed test on the Seagate HDD, too, which gave us exactly the results we had expected (around 220MB/s read and write). We would consider replacing the EVGA SuperNOVA G6 power supply with a higher-wattage model to further future-proof the machine.

This is an expensive PC, especially given the outlandish prices of GPUs right now. The Corsair case and cooler perform as advertised, guaranteeing a cool system ideal for intensive tasks or 4K gaming. If we wanted to trim the price, the first place we'd look is the HDD; 12TB is a huge amount of storage that most people will simply never need. Beyond the eye-watering price tag, though, we're very happy with how this turned out.

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	2,178	4,253 (95%)
CrystalDisk QD32 Sequential Read (MB/s)	3,136	4,901 (56%)
CrystalDisk QD32 Sequential Write (MB/s)	2,126	4,399 (107%)
3DMark Fire Strike Ultra (Index)	6,988	9,790 (40%)
Total War: Warhammer II (fps)	42	64 (52%)
Tom Clancy's The Division 2 (fps)	38	56 (47%)
Metro Exodus (fps)	37	54 (46%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i9-7900X, 32GB G.Skill RipJaws V series DDR4 @ 3,000, an MSI GeForce GTX 1080 Ti Gaming X, and a 512GB Samsung 960 Pro PCIe SSD. All tests performed at 4K at the highest graphical profile. *Metro Exodus* tested at 4K at High.

LAB NOTES

ZAK STOREY, EDITOR-IN-CHIEF

Do-It-Yourself Wall-Mounted PC

I have a plan. Well, sorta...

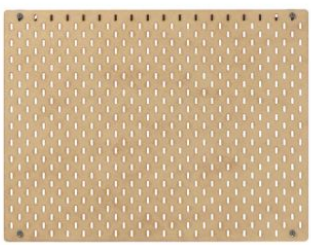
I'VE SPOKEN in the past about my love for Ikea Skadis pegboards. I've got a few dotted around my office, holding everything from headphones, laptops, and PC hardware to a Nordic bearded axe (thanks, Pops!), my sports memorabilia, and even Warhammer paints, and it got me thinking: What if you could turn one into a PC case?

We've seen plenty of wall-mounted PCs, and there's a ton of cases, too. Thermaltake offers one, and there's a few from other manufacturers, but they're usually pricey, cumbersome, tricky to put together, and covered with chunky glass. Traditionally, wall-mounted PCs were made from purpose-cut acrylic or similar, but technically, you could get a Skadis pegboard and convert it into a chassis quite easily. At least, that's what my brain is telling me.

And that's sorta what I think I'm going to do. Maybe not for next issue, but the one after. I'm going to take a white Skadis pegboard, spray it a custom color, create a mounting mechanism for a motherboard, pilfer some parts from the Hydra Mini (including its power button), then, hopefully, build one kick-ass wall-mounted PC.

There are some interesting things to consider. I'll have to cut some of it out to allow breathing room for the AIO. I need to find a way of safely and securely fitting a GPU to it. I need to be extremely clever with cable management, and devise some solution to fit the PSU on there, too (whether that's an SFX or full-size one, I'm still not sure). It's also going to be a pain to shoot, but the photography team and I have a plan for that as well.

The brilliant thing about all of this is that you can get pegboards from Ikea in three different sizes: 14 x 22 inches, 22 x 22 inches, and 30 x 22 inches. That just says ITX, M-ATX, and ATX builds to me! And even the biggest one is only $17, so if I go wrong, it's not a huge loss of investment—and, of course, there's a ton of different accessories I can cajole into being nifty cable management features and such, too.



Imagine this, but with a PC on it.

Bad idea? Maybe. Problems to overcome? Definitely. Going to write up a heck of a feature on it? Absolutely.

SAM LEWIS

Staff Writer

I should probably try some new games for once, but I have jumped back into some PlayStation 2 classics. I remember playing *Gran Turismo 4* all the time with my brother, so I can always get straight back into that. The iconic menu theme tune is stuck with me for life. Other than *Gran Turismo 4,* I've also been back on board with *Star Wars Battlefront II*. By today's standards, the graphics are painful, plus I have it stretched out on a 58-inch 4K TV, but the game is still brilliant. I know you're cringing, but someone's gotta take one for the team. I really need a dedicated old TV or monitor to play these games properly—or do I need to play new games?

ZAK STOREY

Editor-in-Chief

I rang my mother the other day as I was having a rough time. We do most of our communicating via Facebook Messenger as she lives in New Zealand. Years ago, when I used to call via Facebook or even just using a phone, there would be a delay, it would be slow, and it would be hard to have a proper conversation, but this was like she was just down the road, not thousands of miles away. It amazes me how far technology has come even in the last 10 years. And it reminds me why all those years ago, I told her to leave for NZ and not worry about me, and do what made her happiest. Because I knew that tech would bridge the gap, even in tough times.

© IKEA, KLEI ENTERTAINMENT

Editor's Pick: Griftlands

I'm hooked on the replayability of this innovative roguelike

OH, KLEI Entertainment. Will you ever stop knocking it out of the park? *Don't Starve* has long been a favorite game of mine, and *Invisible, Inc.* was a similarly engaging experience, despite the shift to turn-based strategy. Klei's titles stand out with their engaging twists on established formulas, typically combined with a striking, unique art style.

Griftlands is no different, taking the ace gameplay mechanics of card-based roguelike *Slay the Spire* and dressing it up in a cartoonish sci-fi post-post-apocalypse. From the get-go, it's more narrative-driven than most roguelikes. Pick from a selection of three "heroes"—bounty hunter Sal, double agent Rook, or chaotic wastrel Smith—and embark on their own personal journey. Die, and it's back to square one; succeed, and you unlock new challenges, perks, and cards.

While the overall plot of each character's campaign is the same, many story beats are different with each playthrough. The people you encounter vary, drawing from a pool of 241 uniquely crafted characters, from union laborers to alien officials. *Griftlands'* setting is a miserable dog-eat-dog world, a once-thriving planet reduced to its pre-spaceflight era by a largely forgotten cataclysm.

While much of the game revolves around decision-making and conversations, the real meat of the gameplay exists in card-based battles. It's a familiar format: You and your opponent take turns, playing cards from your hand to attack and defend. Your opponents' intentions are displayed above their heads, transforming every showdown into a delicate puzzle as you try your best to counter their planned moves.

Again, this is essentially *Slay the Spire* with some added complexity. Where *Griftlands* innovates is its negotiations; each character has two base decks of cards, one for combat and one for negotiations, both of which can be upgraded and expanded. Negotiations play out differently to combat; you and your unwilling debate partner play cards to chip away at the resolve (read: health) of the other's core argument.

The really good stuff is the cards. Each of the playable characters has distinct mechanics and abilities. You unlock more cards as you progress, adding them to the pool of available loot drops.

Now if you'll excuse me, I'm going to see if Smith can reconcile with his idiot brother, instead of hitting him with a hammer. **–CG**

$20, www.klei.com

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Nvidia GeForce RTX 3070 Ti

8GB of GDDR6X isn't enough

AFTER LAST MONTH'S RTX 3080 Ti left us feeling a little underwhelmed, the RTX 3070 Ti tries to recover. And then stumbles again. They say an elephant never forgets, but what happens when the elephant only comes equipped with 8GB of memory? Sure, it's faster memory this time, with GDDR6X replacing the 3070's GDDR6, but that doesn't feel sufficient for the $100 jump in price—and let's be real, almost no one will be able to buy the RTX 3070 Ti for $599 anytime soon.

If the market were normal, the 3080 Ti and 3070 Ti likely would have launched at the 3080 and 3070 price points, pushing those cards down to lower tiers. But the pandemic and global shortages coupled with cryptomining—all of which are thankfully starting to taper off—mean Nvidia can sell everything it makes, and then some. The bigger problem stems from getting enough parts to sell, which is why prices are going up.

Nvidia claims these new cards were planned for months in advance, meaning chips were already allocated and these products are in addition to what was already on the market. If correct, that would mean more supply and more cards for people to buy. So far, that doesn't seem to have mattered—even with the hash rate limiters now in effect on all of Nvidia's Ampere GPUs (except the RTX 3090). But with China cracking down on miners (see "Tech Talk," pg. 13), there's hope things will improve significantly in the coming months.

Performance of the RTX 3070 Ti is good, leading the 3070 by around 10 percent across our test suite, but it seems to depend more on compute and memory capacity than on memory bandwidth. The 3070 Ti offers 7 percent more theoretical compute and 36 percent more bandwidth, meaning the extra speed of GDDR6X mostly goes untapped. With pricing landing halfway between the 3070 and 3080, but performance that tracks closer to the 3070, the RTX 3080 still ends up being the best option in our book.

Power consumption also ends up being 70W higher than the 3070. That's more than a 30 percent increase, and it's mostly thanks to the GDDR6X memory. At least the 3070 Ti doesn't have as much difficulty cooling the memory—there's less of it, after all—but we can't help but think vanilla GDDR6 clocked at 16Gb/s would have been a better choice, particularly if Nvidia doubled down on capacity like AMD did with its RX 6800 and above, or like it did with the RTX 3060.

Lest we forget, this isn't the first time Nvidia has been stingy with VRAM. The GTX 1060 came in 6GB and 3GB variants, while AMD's competing RX 470/480 offered 4GB or 8GB at slightly lower prices. But those were mainstream GPUs; the RTX 3070 Ti is a high-end product, and it feels like Nvidia's entire RTX 30-series stack (outside of the 3090) has less memory than we'd like. 8GB became the norm for high-end cards five years ago, and now it's the minimum we'd recommend for a mainstream product.

Considering you can pick up an RX 6800 with 16GB of memory for less than the cost of the RTX 3070 Ti, on eBay at least, and that the RX 6800 generally performs better—until or unless you enable ray tracing and DLSS—this isn't a very impressive showing for Nvidia. It's still slightly faster than 2018's RTX 2080 Ti and at a lower price, but less memory and higher power use for roughly equivalent performance after nearly three years? Yawn. Wake us up when Lovelace launches (hopefully in 2022), and maybe by then supply and pricing will be back to normal. –JARRED WALTON

BENCHMARKS

	Nvidia GeForce RTX 3070 Ti	Nvidia GeForce RTX 3080	Nvidia GeForce RTX 3070
10-Game Average (fps)	90/58	**101/66**	82/52
Assassin's Creed Valhalla (fps)	75/48	**79/54**	70/44
Borderlands 3 (fps)	91/52	**111/65**	85/48
Control (fps)	104/69	**109/71**	97/63
Cyberpunk 2077 (fps)	69/46	**71/48**	64/42
Dirt 5 (fps)	108/71	**124/85**	97/64
Horizon Zero Dawn (fps)	112/69	**130/79**	103/59
Metro Exodus (fps)	84/54	**102/67**	79/50
Red Dead Redemption 2 (fps)	87/59	**104/72**	80/54

Best scores are in bold. All testing conducted with a Core i9-9900K, MSI MEG Z390 ACE, 2x 16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores are average frame rates at 1440p/4K Ultra.

VERDICT **7**

Nvidia GeForce RTX 3070 Ti

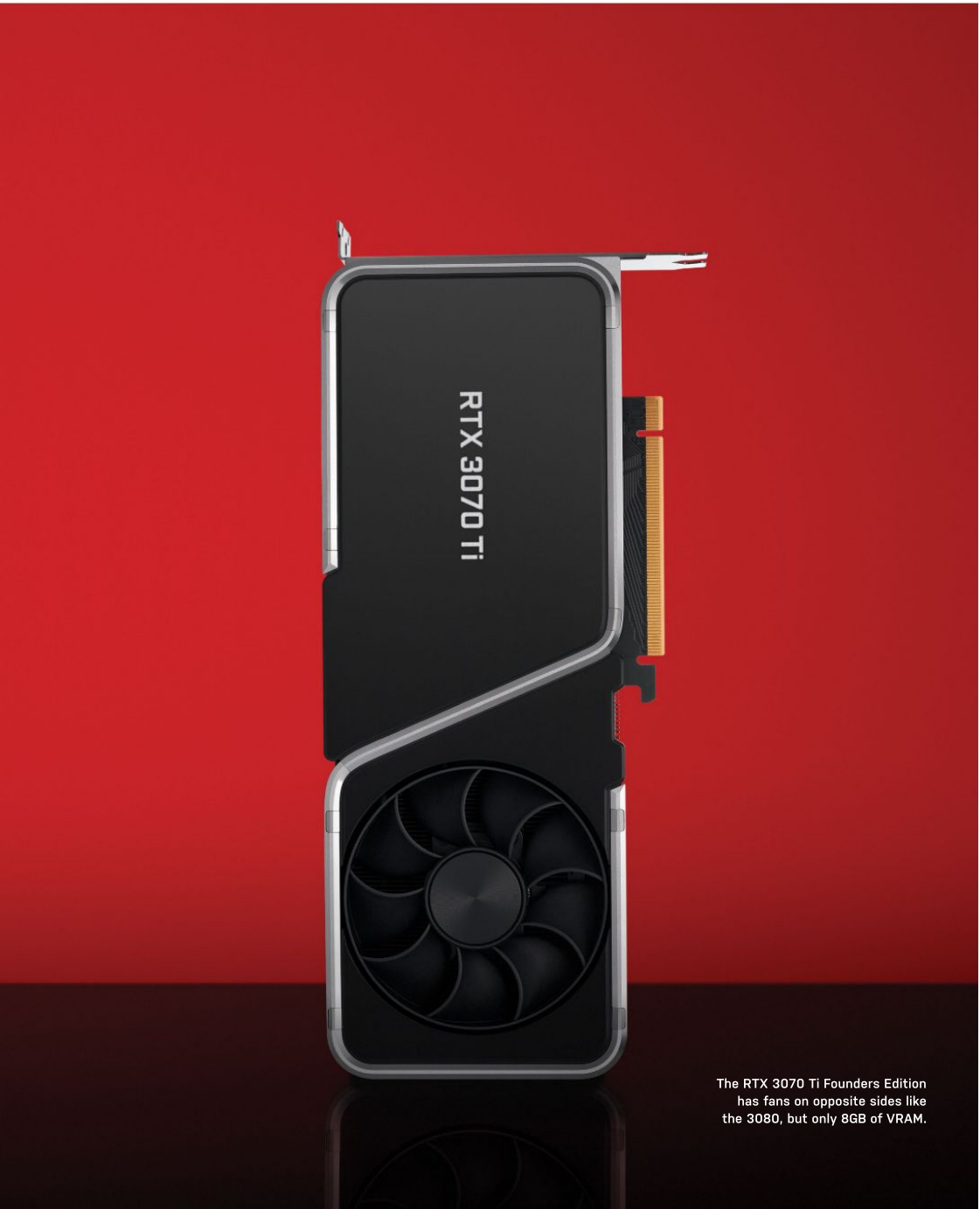
➕ ELEPHANTS Good performance; proven architecture; maybe more supply.

➖ MICE 8GB feels stingy; big TDP jump; not much faster than 3070.

$600, www.nvidia.com

SPECIFICATIONS

Architecture	GA102
Lithography	Samsung 8N
Boost Clock	1,765MHz
GPU Cores	6,144
Memory	8GB GDDR6X 19Gb/s
TFLOPS FP32	21.7
Bandwidth	608GB/s
TDP	290W
Connectors	1x HDMI 2.1, 3x DisplayPort 1.4



The RTX 3070 Ti Founders Edition has fans on opposite sides like the 3080, but only 8GB of VRAM.

Does its strong utilitarian design reflect the power underneath?

MSI Pulse GL66 11UDK

Entry-level ray tracing on a budget

MSI'S BUDGET LAPTOPS are always intriguing. They seem to nail a lot of the essentials that make up a gaming laptop, yet other features are left on the back burner. Of course, performance is the most important factor when it comes to gaming, so maybe we're being harsh, as there have to be sacrifices at this price. So, without this pre-judgment, how does the Pulse GL66 11UDK shape up?

Like many other MSI machines, the design is very utilitarian. We like this from MSI; it isn't unique to the company, but you can easily tell it's an MSI product. Its monochrome color scheme features a black angled chassis with a shield-like lid in shimmering titanium gray, with a black outlined MSI logo sitting proudly in the center. MSI has certainly made the most of the cheaper plastic materials in play here, without making it feel cheap. It isn't the lightest of laptops, which makes it feel more sturdy than it probably is. This is a double-edged sword, however, as it makes it less practical to carry around, too. The GL66 11UDK also has plenty of radiator vents around the chassis, which is great for ventilation and cooling.

When you open the lid, you're greeted by a decently sized backlit keyboard, with the bonus of a mini number pad. Such a small addition, but it helps with productivity. The travel in the keys is fairly deep, so typing on this laptop is enjoyable. The keys also feature an MSI font, which not everyone will love, but there you go. We aren't done with the keyboard yet, so hold your horses. Some Fn controls include fan speed, battery mode, a webcam button, and even a crosshair icon for those intense FPS battles. All things that aren't necessary but are nice touches nevertheless. Unfortunately, things go south a little below the keyboard. The trackpad isn't the largest for a 15-inch laptop, and it's also not the most accurate, with one-handed highlighting in text documents being trickier than normal.

The 15.6-inch IPS panel is a definite positive, though. With thin bezels around the top and sides, it creates a nice level of immersion when gaming. It's a full HD panel and although we would love to see a QHD display here, this is in the budget market, so it's exactly what we'd expect. The colors are nice and crisp, and paired with a refresh rate of 144Hz, it's a great screen to game on. Even with a fairly thin top bezel, MSI has managed to squeeze in a 720p 30fps webcam. Not the best we have seen on a laptop, but it does the job; the colors are somewhat dull, but a well-lit room will help with this.

Heading into the guts of this machine, we have a 53.5Whr battery, which, when tested, isn't great if you want to use the laptop for productivity purposes. It charges pretty quickly, but runs out within four to five hours on full power mode, and gaming drains it even faster, so we recommend keeping it plugged in when you can. One of the main selling points for this laptop is its new Intel Tiger Lake-H processor, the i7-11800H. This is the core that pulsates through the machine, and when paired with its RTX 3050 Ti, gaming is smooth and enjoyable. You can't run everything at max settings, but with the right tweaks, you can easily get a 1080p 60fps experience. As the benchmarks show, it just can't handle it when the sliders are all to the right, but it's not the end of the world. In a budget gaming laptop, that's exactly what you would expect. Again, like most laptops in this price range, the speakers aren't a stand-out feature, and most people will be gaming with headsets anyway, so it's not the biggest issue.

Unfortunately, as we said at the start of the review, there are just a few things that hold MSI machines back, and this is no different. In terms of gaming, it does exactly what it should. With a mouse, you eradicate all of the trackpad woes, and gaming at solid frame rates (even with ray tracing on) is possible. Pretty impressive for the price, so that gets a big thumbs up. For a laptop, though, it's missing good battery life, the trackpad is lacking, and portability isn't great. It's not a perfect all-around package, but as a cheaper gaming rig, you'll be happily impressed with this machine. **–SAM LEWIS**

VERDICT 8

MSI Pulse GL66 11UDK

STRONG PULSE Decent 1080p gaming; good 144Hz refresh rate; satisfying keyboard.

NEEDS DEFIBRILLATION Not quite future-proof; cheap use of materials; unimpressive battery life; small trackpad.

$1,299, www.msi.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,030	1,746 (70%)
CrystalDisk QD32 Sequential Read (MB/s)	3,374	1,986 (-41%)
CrystalDisk QD32 Sequential Write (MB/s)	2,530	938 (-63%)
3DMark: Fire Strike (Index)	13,610	12,353 (-9%)
Rise of the Tomb Raider (fps)	92	107 (16%)
Total War: Warhammer II (fps)	62	54 (-13%)
Tom Clancy's Ghost Recon: Wildlands (fps)	49	42 (-14%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the Acer Predator Triton 500, with an Intel Core i7-8750H, Nvidia GeForce RTX 2060 Max-Q, and 16GB of DDR4-2666. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	Intel i7-11800H @ 2.3GHz
Graphics	Nvidia GeForce RTX 3050Ti GDDR6 8GB
RAM	16GB DDR4 @ 3,200MHz
Screen	15.6-inch IPS @ 144Hz
Storage	512GB NVMe SSD
Ports	1x Type-C USB 3.2 Gen1, 2x Type-A USB 3.2 Gen1, 1x Type-A USB 2.0, 1x RJ45, 1x (4K @ 60Hz) HDMI, 1x mic-in/headphone-out combo jack
Connectivity	Gigabit LAN, 802.11ax Wi-Fi 6, Bluetooth v5.2
Weight	4.9lb
Size	0.9 x 10.1 x 14.1 inches

Alienware M15 R5

Close encounters of the Ryzen kind

ONE THING'S FOR SURE: Alienware laptops remain beautiful pieces of hardware, even if there has been the odd bum note in Dell's handiwork over the years. The M15 R5 (specifically the Ryzen Edition we're reviewing) is no exception, with a stylish exterior and bright RGB lighting. The new R5 only comes in "Dark Side of the Moon" black, which looks great despite its pretentious titling.

It's a little thicker than its predecessor, bucking the trend in gaming laptops getting thinner and thinner, but the M15 R5 is still on the slender side when it comes to portable powerhouses. Inside, we've got a Ryzen 7 5800H processor and an RTX 3060, for about double what you could expect to pay for that GPU right now. This is Dell's first Alienware laptop with a Ryzen processor and an RTX GPU, so it's exciting to see how it could measure up against Intel-powered laptops.

Were we not in the midst of a serious hardware drought, a laptop like this might look less appealing. With only a 256GB SSD and 16GB of RAM in the base model, the specs feel a little under par for the asking price compared to some competitors. The display has a high refresh rate of 165Hz with 3ms latency, but when it comes to visual clarity and color reproduction, it's a fairly standard 1080p panel. We can't help but wonder if you couldn't pick up a laptop with an RTX 3070 or a better screen without leaving the R5's immediate price range.

Value grumbles aside, though, the M15 R5 does offer good performance for a gaming laptop, squeezing everything it can get out of that RTX 3060. The Ryzen processor is great, kicking ass in CPU-bound games, and works wonders for the M15's battery life (although this is still a gaming laptop, so using it plugged in is the best option to prevent GPU power throttling). The M.2 SSD's performance was sub-par, but you won't notice a difference between this and a high-end drive in games.

HOT TOPIC

We did find that the M15 got particularly warm, both during testing and when idling for any significant length of time. The fans and vapor chamber cooling work well, so there's not much of an issue with hot air blasting from the sides while you're working, but the underside gets uncomfortably warm very quickly, meaning that you can't really put this laptop atop your lap. The keyboard area doesn't get too hot, so if you place the M15 on a surface to use it, you should be fine.

That lackluster memory and storage we mentioned? Well, the good news is that it's user-upgradable, with an easy-to-unscrew panel on the underside of the chassis. Unfortunately, the physical benefits of the M15 R5 end there; the keyboard is nice to use, but it's fallen victim to a weird layout rejig that sees the volume control keys squeezed into a vertical row on the right-hand side. The trackpad is the same seen in previous M15 models, which means it has a satisfying click but is altogether too small for a 15-inch laptop.

The ports on offer here are also somewhat limited, with many of them shunted to the laptop's rear edge, which could prove irritating for anyone working with limited desk space. The dual integrated speakers perform adequately, but we've definitely seen laptops with better audio solutions.

The M15 R5 does, at times, feel like a trial run for Dell. The Alienware brand is dipping its toe back into AMD waters, and this laptop serves as proof of concept for that; there are teething issues, many stemming from Dell's attempts to subtly rework the physical design of the standard M15 chassis, but the 5800H does great. Models range from $1,300 to $2,380, with the top-spec R5 using a Ryzen 9 5900HX and an RTX 3070. It's surprising not to see a SKU with a more powerful GPU, but again, Dell is still testing the waters. It'll certainly be interesting to see what comes next. **–CHRISTIAN GUYTON**

VERDICT **7**

Alienware M15 R5

ALIEN Good gaming performance; clean aesthetic; upgradable RAM and SSDs.

PROMETHEUS Runs hot; poor value for money; new keyboard layout is weird.

$1,600, www.dell.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,030	1,686 (64%)
CrystalDisk QD32 Sequential Read (MB/s)	3,374	2,348 (-30%)
CrystalDisk QD32 Sequential Write (MB/s)	2,530	1,427 (-44%)
3DMark: Fire Strike (Index)	13,610	17,969 (32%)
Rise of the Tomb Raider (fps)	92	105 (14%)
Total War: Warhammer II (fps)	62	81 (31%)
Tom Clancy's Ghost Recon: Wildlands (fps)	49	56 (14%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the Acer Predator Triton 500, with an Intel Core i7-8750H, Nvidia GeForce RTX 2060 Max-Q, and 16GB of DDR4-2666. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	Ryzen 7 5800H
Graphics	Nvidia GeForce RTX 3060 6GB
RAM	16GB DDR4 @ 3,200MHz
Screen	15.6-inch FHD 1080p screen @ 165Hz 3ms
Storage	256GB M.2 NVMe SSD
Ports	1x HDMI, 2x USB 3.2 Gen1 Type-A, 1x USB 3.2 Gen2 Type-A, 1x USB 3.2 Gen2 Type-C, 1x RJ45 Ethernet, 1x 3.5mm global headset jack
Connectivity	Killer Wi-Fi 6, Bluetooth 5.2
Weight	5.34lb
Size	0.9 x 10.7 x 14.0 inches

The chiclet keyboard has customizable four-zone RGB lighting.

LG UltraGear Ergo 27GN880-B

An ergo-armed work-play curiosity

A PC MONITOR that pleases both gamers and productivity peeps? Sounds like a stretch, but that's the new LG UltraGear Ergo 27GN880-B's basic proposition.

The gaming half of the equation is covered by 144Hz of Nano IPS panel tech. LG claims it's good for 1ms response times. That's courtesy of the gray-to-gray metric, not the tricksier MPRT measure, which can flatter to deceive regarding the subjective experience of pixel speed.

Support for both AMD FreeSync and Nvidia G-Sync flavors of adaptive refresh is also included. Combine all that with the popular 27-inch form factor and 1440p native resolution (2560x1440 pixels), and you have a solid base for a gaming panel. There are panels with more pixels. There are monitors with higher refresh. But that 144Hz, 27-inch, 1440p, 1ms combo from an IPS panel is a real-world sweet spot. Few gamers will truly need more.

As for productivity, the most obvious element is the name. This Ergo monitor sports an asymmetric stand that clamps to a wide range of desktops measuring up to 3.5 inches thick. It offers a really wide range of adjustment, including 280 degrees of swivel, 18cm of extend and retract, plus pivot into portrait mode. You basically just grab the thing and position it where you want. It's pretty neat.

The stand includes some clever cable management, too, by routing everything through the main arm, down to the base. Perfect if desk space is at a premium.

Speaking of cables and connections, arguably the LG 27GN880-B's most obvious shortcoming is the absence of USB Type-C. That's a pity. Being able to hook up a laptop via a single cable would really suit this monitor's overall vibe.

Still, the LG UltraGear Ergo 27GN880-B clocks in with some pretty impressive color fidelity, with 98 percent coverage of the DCI-P3 gamut. The sole snag is that sRGB is the only color space preset in the OSD. Anyway, while the LG 27GN880-B isn't an out-and-out pro display designed for high-end workflows, such as mastering video, it is a plausible panel for light content creation.

It's also a very nice gaming panel. Most impressive is the speed and response. LG includes three levels of user-configurable pixel overdrive in the OSD menu. In truth, the fastest option is a bit of a mess and suffers from obvious overshoot. But the middle setting is super-sharp. Only the very quickest TN panels offer better response, at the cost of contrast, viewing and color accuracy.

Slightly less impressive is the overall punch. At 350 nits, it's not dingy, but in this age of 1,000-nit HDR eye-scorchers, the experience is conspicuously SDR. For the record, HDR10 signal decoding is supported. And not only does HDR content look decent, SDR content is also handled well in HDR mode. But this is not a true HDR panel. There's no local dimming and peak brightness is nowhere near what's required for sufficient dynamic range.

All told, the LG UltraGear Ergo is an appealing curio. It's more convincing as a gaming panel than a productivity tool, for sure. But if you're looking for a monitor that can also turn its hand to more serious affairs, as well as improve the ergonomics of your desk space, stick it at the top of your shortlist. –JEREMY LAIRD

VERDICT **9**

LG UltraGear Ergo 27GN880-B

➕ COGITO, ERGO SUM Speedy IPS panel; super ergonomics; good color accuracy.

➖ ZERO SUM GAME No USB-C connectivity; limited color space presets

$397, www.lg.com

SPECIFICATIONS

Panel Size	27-inch
Panel Type	Nano IPS
Resolution	2560x1440
Brightness	350 nits
Color Coverage	98 percent DCI-P3
Refresh	144Hz
Contrast	1,000:1
Response	1ms GtG
Adaptive Refresh	FreeSync, G-Sync
Inputs	2x HDMI, 1x DisplayPort

LG's 27-incher combines 144Hz gaming fun with superb ergonomics and strong color accuracy.

Corsair 7000D Airflow

More cooling! More cooling!

CORSAIR IS GOING BIG, with a new full-tower PC case and a new cooler to go with it; that's the iCUE H170i Elite Capellix RGB seen in this issue's "Build It," an AIO unit with a whopping 420mm radiator. The 7000D Airflow is the case built to house such a chunky cooling solution, and it certainly lives up to its name.

Let's start by talking about fans and radiators. The 7000D comes with three non-RGB 140mm fans, but there's space for plenty more—the front can handle up to four 120mm fans (or three 140mm), and the same goes for the upright cooling bracket that sits behind the cable cover plate on one side. At the top of the case, there's a removable rail bracket that can support 420mm of radiator space, and there's naturally a vent for a single pre-installed 140mm fan at the rear.

Using all these concurrently isn't quite an option, as large radiators mounted to the front and top can encroach on each other, but there's undeniably space for plenty of workstation-level cooling here. The front and top panels are highly perforated steel to allow for superior airflow, with magnetic dust filters and hinged side panels, one of which is a full glass window. Taking the 7000D apart to build in is a relatively painless process.

The massive 80-liter interior allows for some chunky builds, with extended ATX mobo support and enough GPU clearance to handle the biggest RTX 3000-series cards. A windowed PSU shroud runs along the bottom of the case, allowing you to view your power supply (handy if you're rocking a PSU with an integrated display, such as the Asus ROG Thor) while also concealing a pair of drive cages, each of which can hold three HDDs or SSDs.

Elsewhere, we've got four dedicated mounting plates for 2.5-inch SSDs, and a variety of plastic and metal contraptions for routing and concealing cables. The rear of the motherboard plate actually hides behind a second, smaller hinged metal panel beneath the vented side panel, ensuring a tidy appearance regardless of how your cable management skills are.

Although some serious case-modding would be required to fit a second ITX system in here, Corsair is evidently comfortable with modders using the 7000D for esoteric projects. Several additional brackets are included in the box (such as a vertical mount that anchors to the PSU shroud for showing off your GPU) and almost all of the extraneous parts can be removed with a humble Phillips screwdriver, from the drive cages to the built-in fan hub.

Even with all the extras removed, this is still a seriously heavy case. With its full-tower form factor comprising over 40 pounds of steel, plastic, and tempered glass, the 7000D can be a nightmare to move around, especially when building in it. The build quality here is superb, though, with every part feeling sturdy and well crafted. It's little wonder that it costs so much; the hefty $260 price tag is a gut punch, but it's at least in line with competing full-tower cases from the likes of Lian Li and Fractal Design.

The front I/O is very well equipped, offering four USB-A 3.0 ports along with USB-C and a headphone jack. There aren't any RGB control buttons to be found here; the 7000D favors a more muted appearance, as evidenced by the dark tint on the window panels. It's hard to deny that this is one of Corsair's best-looking cases, both in the black model we're reviewing and its vivid white counterpart.

This isn't a case for the workaday PC-builder, with its gargantuan frame and roomy, feature-packed interior. But it's certainly an excellent choice for anyone who needs a large-scale build, whether that's a central system packed with NAS drives or a supercharged editing rig. With smart design choices that make building easy (barring its overall bulk), the 7000D is one of the best full-tower cases we've seen in years. –CHRISTIAN GUYTON

VERDICT **9**

Corsair 7000D Airflow

+ ARCTIC Top-notch build quality; loads of space for drives and cooling; good front I/O.

– SAHARA Fairly expensive; as heavy as it gets.

$260, http://corsair.com

SPECIFICATIONS

Form Factor	Full tower
Motherboard Support	E-ATX, ATX, mATX, ITX
Colors	Black, white
Window	Yes
3.5-Inch Support	6
2.5-Inch Support	4 + 6
Radiator Support	480mm (front), 420mm (top), 480mm (side), 140mm (rear)
Fan Support	3x 140mm (front), 4x 120mm (top), 4x 120mm (side), 1x 140mm (rear)
Dimensions	9.8 x 21.7 x 23.6 inches
Graphics Card Clearance	17.7 inches
CPU Tower Clearance	7.5 inches
Weight	41.2lb

A hefty home for a supremely cooled system.

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SK Hynix Gold P31 1TB

Give your PC some affordable TLC

WHEN IT COMES to SSDs, it's all too easy to become obsessed with numbers. The latest PCIe Gen 4 drives knock out six or seven gigabytes per second of raw bandwidth. Not long ago, figures like that wouldn't have looked too shabby for RAM or system memory, let alone storage.

Thing is, there's a lot more to storage performance than peak throughput. That's good news for the new SK Hynix Gold P31, an M.2 NVMe SSD sampled here in its 1TB version. It makes do with a quad-lane PCIe Gen 3 interface, limiting peak theoretical performance to 4GB/s rather than the 8GB/s of Gen 4 drives.

Of course, for a lot of legacy PCs, the very idea of PCIe Gen 4 is rather fanciful. Until the launch of the new Rocket Lake CPUs earlier this year, there were no desktop Intel platforms with Gen 4 support. On the AMD side of the equation, it didn't arrive until the third-gen Ryzen chips appeared in 2019.

Despite the competitive pricing, however, this is not an out-and-out budget drive. Most importantly, the Gold P31 uses TLC or triple-level flash memory, rather than QLC or quad-level chips. The big advantage of QLC is data density. You get more memory for your money. The downsides are speed and endurance. As flash memory bit-level density increases, both of those attributes suffer, and sometimes dramatically.

Another indicator that SK Hynix hasn't cut too many corners is the healthy 1GB of DDR4 DRAM cache. As for the Gold P31's controller, it uses SK Hynix's own Cepheus chip, which is unusual in having just four rather than eight memory channels, the latter being the norm for performance-oriented controller chips.

Fortunately, the Cepheus makes up for that by running SK Hynix's own 128-layer flash memory chips at 1,200MT/s—that's around twice the speed of drives based on, say, Micron's 96-layer TLC NAND. Anyway, the overall upshot in terms of claimed performance from this 1TB model is 3,500MB/s for sequential reads and 3,200MB/s for writes.

CACHE FLOW

As with pretty much any modern SSD, those peak numbers apply to the drive running in pseudo SLC or single-level cell mode. The Gold P31 can allocate up to 90GB of so-called SLC cache for this high performance mode. When that's exhausted, the underlying 1,700MB/s performance of the MLC flash memory is exposed.

However, in terms of day-to-day responsiveness, it's 4K random access that can often be more critical. Here the Gold P31 clocks in at 570K read IOPS and 600K write IOPS in SLC mode, while the base performance of the TLC cells is rated at 500K read and 370K write IOPS.

Features-wise, one arguable omission is the lack of hardware encryption support from the controller chip. Data can still be encrypted using software tools, but that comes with a significant CPU load. If you want to run by default with all your data encrypted all the time, that's suboptimal. But most PC users will be happy to encrypt more selectively.

Rounding out the key feature points, SK Hynix overtly highlights the fully biodegradable status of its packaging, which is unusual in this class of device. Arguably more relevant is the healthy five-year warranty, providing long-term peace of mind. For the record, write endurance is pegged at 750TB.

What you really want to know is how fast this is in practice. Peak bandwidth is what you'd expect, with 3.5GB/s in both directions. Random access performance is a little less straightforward. Initial 4K QD1 performance is 74MB/s, dropping to the mid-50s in subsequent runs, hence the relatively unimpressive scaling as queue depth increases.

Sustained performance is likewise in line with the expectations generated by the 90GB of dynamic SLC cache. After 90GB/s of sustained data transfer when copying large video files internally, performance drops from 1.2GB/s to around 900MB/s. That's sustained for a further 200GB, after which the drive fluctuates between 750MB/s and 900MB/s until full. Not stellar numbers, but they should be plenty for all but the most demanding users. –JEREMY LAIRD

VERDICT 9

SK Hynix Gold P31 1TB

+ ALL THAT GLISTERS... Decent all-around performance; five-year warranty.

– ...IS NOT GOLD AES 256-bit encryption; slightly patchy 4K numbers.

$135, www.skhynix.com

BENCHMARKS

	SK Hynix Gold P31 1TB	Samsung 980 Pro 1TB	Sabrent Rocket 4 Plus 1TB
CrystalDisk 6 Sequential Read/Write (MB/s)	3,589/3,463	**7,098**/5,172	7,075/**6,836**
Anvil 4K QD 1 Read/Write (MB/s)	74/188	**83**/194	68/**239**
Anvil 4K QD 2 Read/Write (MB/s)	108/351	**168**/384	134/**435**
Anvil 4K QD 2 Read/Write (MB/s)	212/611	**328**/648	265/**708**
Final Fantasy XIV: Shadowbringers (load time seconds)	11.733	9.902	**8.979**

Best scores are in bold. Our test bench consists of an AMD Ryzen 9 3900X, a Gigabyte X570 Aorus Master, an Nvidia GeForce GTX 1080, 32GB of Corsair Vengeance RGB Pro DDR4, and a Corsair Neutron 240GB OS SSD.

SPECIFICATIONS

Capacity	1TB
Form Factor	M.2 2280
Interface	PCIe 3.0 x4
Protocol	NVMe 1.3
Read/Write speed	3,500/3,200MB/s
Random Read/Write	570K/600K IOPS
DRAM Cache	1GB DDR4
SLC Cache	92GB dynamic
Write Endurance	750TB
Warranty	Five years

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Whirlwind FX Atom

Atomic power clicking up a storm

WHIRLWIND FX'S flagship keyboard is the Element (currently the Element V2, to be precise), a full-scale mechanical keyboard that offers a unique form of reactive per-key RGB lighting. The Atom is essentially the same product trimmed down to a slender 60-percent form factor.

As you are probably aware, that means no numpad, no arrow keys, and no dedicated function keys. This is a barebones keyboard, offering just enough buttons to do everything a standard gaming keyboard should be capable of. Function keys and media controls are printed on the front sides of some keys, activated via simultaneous keypresses with Fn; for example, Fn-Q plays or pauses music on the Atom.

Whether or not a 60-percent keyboard is right for you comes down largely to personal preference, but there are some advantages offered by the Atom's form factor. There's very little bezel space, and the keyboard is just an inch and a half tall at its thickest point, with the rubber-coated feet folded away, making it easy to slip into a backpack for on-the-go use.

The key switches are Gateron models, specifically the Linear Red version for our review unit. They're a lot quieter than we expected (the original Element used Kailh switches, which were quite clattery), and the double-shot ABS matte keycaps feel lovely. The red switches are quite snappy, with a bit of wobble, which makes them undeniably better for gaming than typing. The full N-key rollover and 3,000Hz polling rate are great, giving this keyboard a real feeling of responsiveness in fast-paced games.

The overall build quality is certainly consistent with the $80 asking price, with a durable-feeling matte plastic construction. Unlike Whirlwind's Element keyboard line, the Atom's backplate is bright white anodized aluminum, which serves to effectively accentuate the RGB lighting beneath each key. Power and connectivity are handled by a braided USB-C cable that comes included. A wireless option would've been a good inclusion, but it's not a deal-breaker.

SIGNAL BOOST

The big selling point is the reactive RGB lighting that has become Whirlwind FX's trademark, now controlled via the shiny new SignalRGB software. The LEDs are bright and colorful, with detailed per-key customization available alongside lighting presets, such as the classic rainbow wave.

It's the "reactive" aspect of the Atom's RGB lighting that is simultaneously its greatest asset and an awkward stumbling block. As seen on the Element keyboard, SignalRGB can sync up to a number of games, offering dynamic lighting profiles for each. We tested out the *Apex Legends*, *Overwatch*, and *Hades* integrations, all of which looked great, smoothly reacting to what was happening on screen to great visual effect.

For unsupported games, the Atom offers a system that dedicates invisible grid tiles of your display to individual LEDs on the keyboard, with the lighting mimicking what appears on the screen. New game integrations are being added regularly, with a clear focus on popular triple-A titles. SignalRGB is currently only available for Windows, though, so bear this in mind.

Unfortunately, the Atom loses out to the full-size Element simply due to the lack of prime RGB real estate on the keyboard. With fewer keys and therefore fewer LEDs, the impressiveness of the reactive lighting is, well, less impressive. It still looks good, but we feel that the overall effect loses something for its 60-percent design; the animation of some game integrations feels a little truncated in comparison to the Element.

This is only a minor criticism, though, and that's all the Atom has: surface blemishes that can't undermine the fact that this is a polished product at a sound price. If you want a portable keyboard or are simply looking to free up some desk space, the Atom is a solid 60-percent offering from the RGB masters at Whirlwind FX. –CHRISTIAN GUYTON

VERDICT **8**

Whirlwind FX Atom

PROTON High polling rate; surprisingly quiet; looks fantastic; ultra-compact.

ELECTRON Not the best for typing; 60-percent form factor impacts lighting effects; lacks wireless.

$80, www.whirlwindfx.com

SPECIFICATIONS

Switch Type	Gateron Linear Red/ Clicky Blue/Tactile Brown
Switch Durability	50 million presses
Media Keys	Integrated Alt-keys
Connection	USB-C
Battery Life	N/A
Wristrest	None
Dimensions	11.3 x 3.9 x 1.5 inches

Corsair Virtuoso RGB Wireless XT

Star of the show

CORSAIR'S FIRST CRACK at the Virtuoso was bold—a new flagship headset that tried to bridge the gap between gaming headsets and audiophile headphones. The original Virtuoso SE was released in 2019, and it was a well-loved product with one main criticism: a brutally high price. The Virtuoso RGB Wireless XT is the latest in the line, a slick update to a good design. How much has changed since 2019? Well, in Corsair's world, not much.

The XT is immediately familiar to anyone who had a set of the older Virtuoso cans, from the soft black leatherette cushioning on the headband to the muted gunmetal exterior of each earpiece. A diminutive Corsair logo sits in the center of each earcup, behind which glows subtle, understated RGB lighting. This isn't your average gaming headset, it says. This is something more.

Indeed, on paper, the Virtuoso XT sits at the top of its game. A broad frequency response range, surround sound, and Dolby Atmos audio (the software for which has to be installed separately, but is free) mean the XT should offer stellar sound quality straight out of the box.

We're pleased to report that it does, with incredible clarity in games that allows you to hear higher-pitched sounds such as bullet casings hitting the ground even through the clamor of gunshots and bassy explosions. AptX HD audio results in near-lossless sound, making these a solid choice for listening to music as well (although they won't compete with audiophile cans in the $500-plus price bracket). TV and movies sound amazing here, too, although you'll want to use one of the lower-latency connection options.

When it comes to connectivity, there's a lot to choose from. Wired connections are available via a 3.5mm jack or USB-C to USB-A cable, while the titular wireless works via Bluetooth or Corsair's 2.4GHz Slipstream, which is particularly impressive, showing zero noticeable latency with a range of up to 60 feet.

The battery life is improved from the SE, now sitting at around 15–20 hours of continuous use. The microphone is also great; Corsair refers to it as "broadcast-grade," and while that's something of a stretch, it still performs very well. Vocal quality was excellent both in video calls and game chat. A small ring of light at the end of the flexible boom arm indicates when the mic is muted.

The construction of the Virtuoso XT is just as refined as its predecessor, with plush memory foam padding and a durable metal headband, although the machined aluminum components mean it isn't the lightest headset we've come across. Clamp force on the headband is quite gentle, however, so the XT isn't uncomfortable to wear for long periods. The buttons and volume wheel feel immensely well made, with a degree of tactility that is unbeaten by competitors.

Of course, all this still comes with a hefty price tag. The Virtuoso RGB Wireless XT costs $270, far more than you need to spend on a good-quality gaming headset. The Razer Nari Ultimate, Logitech G533 Wireless, and Corsair's own HS60 Haptic headset all cost $100–$150, and are all great choices. If you can afford it, though, the Virtuoso XT is a stunning set of headphones, perfect for any fan of both gaming and music. –CHRISTIAN GUYTON

VERDICT
9
KICK ASS!

Corsair Virtuoso RGB Wireless XT

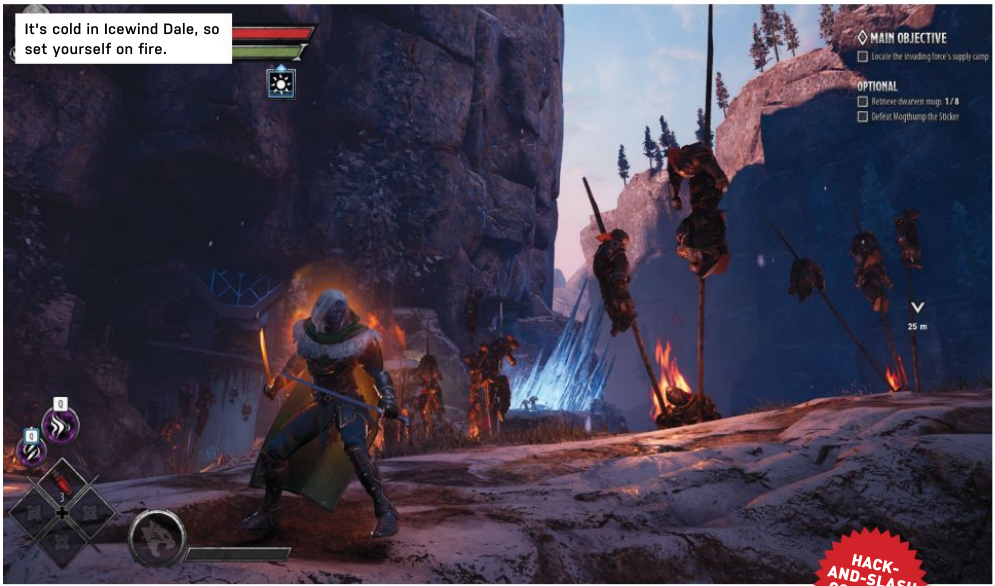
VIRTUOUS Great audio; versatile connectivity; good construction quality; solid mic.

SINFUL High asking price.

$270, www.corsair.com

SPECIFICATIONS

Driver Type	50mm neodymium magnet
Frequency Response	20Hz–40kHz
Sensitivity	-42dBV
Design Style	Circumaural, closed back
Microphone Type	Omnidirectional noise-canceling electret condenser
Connection Standard	3.5mm wired, USB-A wired, Bluetooth, USB-C, 2.4GHz wireless
Battery Life	15 hours
Weight	0.84lb


It's cold in Icewind Dale, so set yourself on fire.
MAIN OBJECTIVE
Locate the invading force's supply camp
OPTIONAL
Retrieve dwarven mugs: 1/8
Defeat Mogthump the Sticker
25 m

HACK-AND-SLASH CO-OP RPG

Dungeons & Dragons: Dark Alliance

Fantasy hack-and-slash that lacks one major feature

WHILE THE FORGOTTEN REALMS can be a very welcoming campaign setting—just see the sandy beaches of *Baldur's Gate III* for more on that—there's a part of it, Icewind Dale, that is inhospitable and practically repels adventurers. And yet they keep setting games there.

Dungeons and Dragons: Dark Alliance is a successor to the *Baldur's Gate: Dark Alliance* games of the mid-'00s, rather than the Infinity Engine titles of a few years earlier. This means a hack-and-slash action-RPG rather than anything with too many dice-rolls behind the scenes, and a slip into a third-person viewpoint from the traditional top-down look.

Powered by Unreal 4, this is a game built with co-op in mind. That's not to say you can't solo it, but playing it on your own feels as though something is missing. And, sadly, the developers have fallen into the most common co-op trap: There's no local option.

Dark Alliance was always best with two players on the same couch, throwing themselves into hordes of zombies, skeletons, drow, or lizardfolk, watching each other's backs, and squabbling over loot. Played online, with someone you're not familiar with and who may or may not be available on voice chat, is just not the same experience. The death of local co-op is one of the worst things about the current videogame scene, and that's a hill we're prepared to die on.

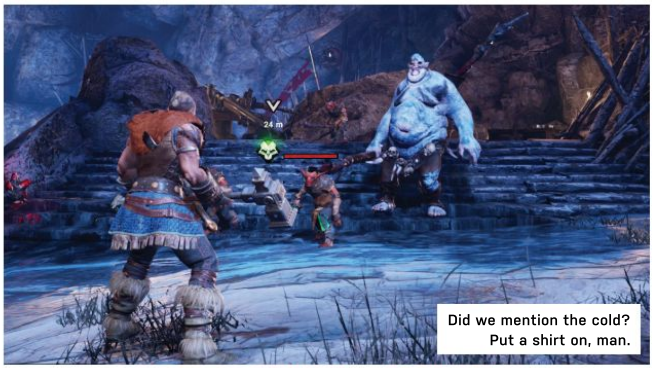
Luckily, a ready supply of health potions prevents too many deaths while playing the game, although the steady stream of mini-bosses strewn throughout the goblin hordes means that lone players may find themselves turning to drink more often—they're designed to be pulled and kited by a tank while a damage-dealer sneaks around the back. Reviving dead comrades is easy to do when you're in a group, but when solo, you're reliant on respawn points.

As you progress through the halls and dungeons beneath Icewind Dale (popular *Dungeons & Dragons* author R. A. Salvatore is involved, and the game ties in with some of his books, the reading of which will improve your appreciation of the game, apparently, although he would say that, of course), you'll pick up collectibles and accrue experience points. All the leveling and equipping, buying and selling, is nicely constrained to the hub area, where you'll find everything you need for a satisfying adventurer experience. It keeps the combat streamlined, because no one's left standing still while their player opens up interminable menus. You can even buy new combat moves before heading back into the fray to try them out.

BONFIRE OF THE RARITIES

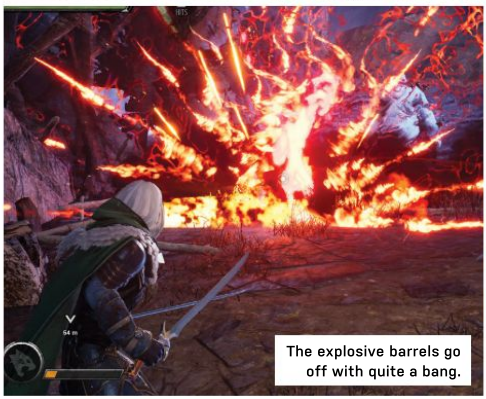
The best moves, however, are team-based, and rely on you having collected together a group that's of a similar level and which has unlocked complementary skills. The online matchmaking seems a little random in this regard, though it may be doing its best with a shallow pool of possible teammates, often matching with those of far too high or low a power level. Resting at bonfires during a delve into the depths allows you to heal and sets a new checkpoint, but ignoring the warmth of the flames increases the rarity of the loot

© WIZARDS OF THE COAST



Did we mention the cold? Put a shirt on, man.

Chests full of rewards are liberally scattered around.



The explosive barrels go off with quite a bang.

You often see mini-bosses from some distance, waiting for you.

you'll find, making for a neat trade-off between survival and cool stuff.

The switch to third-person perspective is a good thing for *Dark Alliance*, as it allows it to show off the architecture and height of its enemies, while the top-down camera mainly showed floor and the tops of heads. Pushing things up to Ultra, however, doesn't give a particularly fine result. This is partly because of a massively strong motion-blur filter that needs to be turned off (we thought we'd got some great screenshots of a mini-boss vomiting over our character as we took it down, but the result nearly made us do the same thing) and partly down to a lack of anything more interesting than rock, snow, and bright-red explosive barrels in many of the backgrounds. (A crystal fortress in the mountains, however, and a dwarven forge still filled with molten metal are imaginative standouts.)

It's all very linear, though, with none of the exploration you'd expect in an open-world RPG. But it does have character. Goblins sneer and invitingly pat their backsides before you put a warhammer through their heads, and any R. A. Salvatore-adjacent property that includes Drizzt Do'Urden cannot be said to be uninteresting. Enemy choice is good, too, although it gets off to a slow start with the aforementioned goblins. Once you're fighting teleporting cultists or regenerating trolls, there's a lot of tactical play on offer, but this underlines how much the game is meant to be played in a group. The AI activation distance is also strangely short, enabling you to pepper foes with ranged attacks without them, apparently, even noticing.

Alongside Drizzt, who is fast, with twin swords, and a spirit panther special attack, you can fight as the dwarf Bruenor, who is as slow and tanky as you'd expect. Then there's Wulfgar the barbarian, with a powerful hammer and fiery special, and Cattie-brie the fragile archer. Strong and weak attacks, parries, and blocks make up the bulk of combat, although each character has a ranged attack that's mainly useful for setting off barrels unless you're Cattie-brie. Charge up your bar at the bottom of the screen with enough killing, and you can unleash your special to do some more. It's a simple system that builds nicely in co-op, but leaves you open to being swamped by crowds when playing alone, unless you can keep your special attack charged up.

Local co-op or bots are desperately needed in games like this, and we hope the devs can patch this in soon. As it stands, this is a game that will delight a regular group, moderately amuse someone looking for quick matches, and leave the solo adventurer wishing they'd stayed back at the inn. –IAN EVENDEN

VERDICT 7

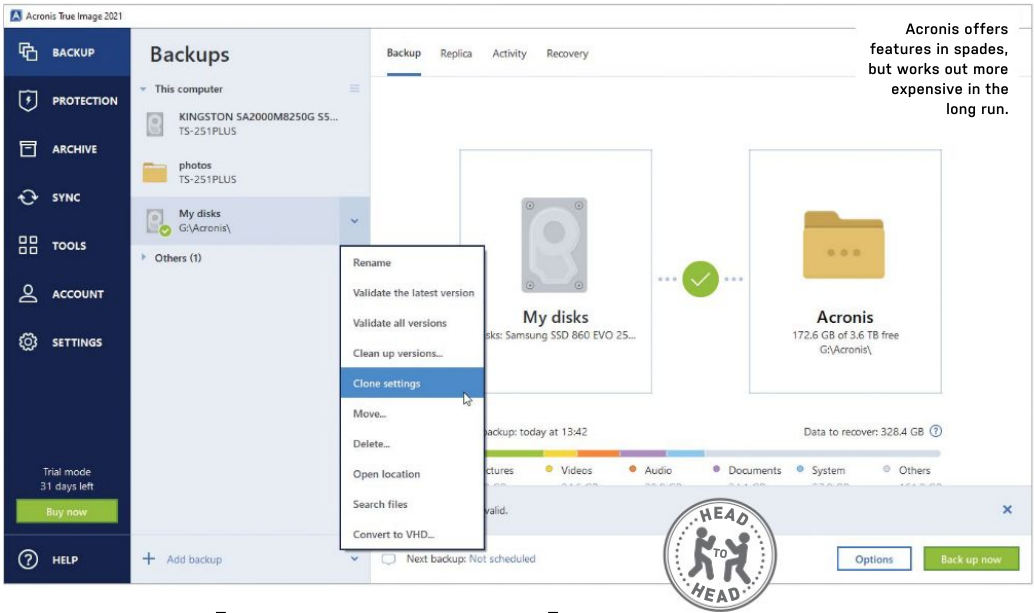
Dungeons & Dragons: Dark Alliance

DRAGONS Good fun in co-op alongside people you know and play with regularly.

DUNGEONS For the rest of us, local co-op or bots are much-needed additions.

RECOMMENDED SPECS R5 3600/i5-9600K; 16GB RAM; RX Vega 56/GTX 1660Ti.

$40, http://darkalliance.wizards.com, ESRB: M



Acronis offers features in spades, but works out more expensive in the long run.

Acronis vs. Macrium

Which drive-imaging app offers better protection?

EVERYONE NEEDS a reliable backup tool, and as we outline on page 28, that should include a full drive image of your entire system, giving you the ability to restore your PC to working order with minimal disruption in the event of disaster. This issue, we're pitting two drive-imaging tools against each other: Macrium Reflect 8 Home Edition is the paid-for version of our favorite free drive-imaging tool, while Acronis TrueImage 2021 is a long-established and trusted heavyweight.

But do you even need to pay for a drive-imaging tool? Macrium Reflect Free has protected our PCs for years, but there are some niggles that both the Home edition and Acronis resolve, the main one being support for incremental backups. These make daily (and even intra-daily) backups practical thanks to the fact they're smaller and faster than differential backups.

Both paid-for tools support password-protected encrypted drive images for greater security, too, as well as protection against ransomware, which could infect your backups. Both also allow you to back up individual files and folders. But which one offers the most bang for your buck?

Acronis TrueImage offers you a choice of tiers, while Macrium Reflect 8 Home Edition is a single product. Acronis adopts subscription-based pricing, starting at $49.99 per year for the Essential tier. This entitles you to the next major release—Acronis TrueImage 2022 is imminent. It also offers two additional tiers, both of which come with added anti-malware protection (nothing to write home about, but reasonably solid aside from a weakness against browser phishing), alongside cloud storage to let you to store backups off-site.

Upgrading to cloud storage may seem like a no-brainer, but while the premiums are reasonably competitive—$89.99 a year for 500GB or $124.99 a year for 5TB of cloud storage—there's a major catch: Unless you have a super-fast connection, it'll take forever to upload a full drive image. When compared to other cloud providers, Acronis isn't the quickest either.

Macrium Reflect offers no option to back up to the cloud or any anti-malware components, but this is reflected in its price: a one-off $69.99 for version 8. Macrium Reflect 7 debuted in early 2017, so version 8 will probably last you several years—and naturally covers all 8.x updates, which are likely to contain several new features if the previous version's life cycle is anything to go by. If you're looking to protect your entire household, a four-PC license for $139.95 is also available.

HOW THEY COMPARE

Acronis TrueImage's interface feels like an attempt to pitch itself to a less technical audience, illustrated perfectly by the backup wizard. At first glance, you simply choose your source and destination, then click "Back up now." In reality, you need to spend time on the multi-tabbed "Options" screen, setting up both fundamentals such as scheduling and backup type, along with optional tweaks, most of which are buried away under the "Advanced" tab.

Macrium invites you to choose a backup type from its main screen: image selected disks, image system partitions, or files and folders. From here you confirm your selection and choose a destination, then set your schedule before reviewing your settings and clicking "Backup." Again, "optional" extras are hidden behind an "Advanced" dialog, and it's here we administer a slap on the wrist to both products for requiring you to check a well-hidden box to automatically verify backups after they've been completed.

We tested both by performing a full backup of our system and data partitions—

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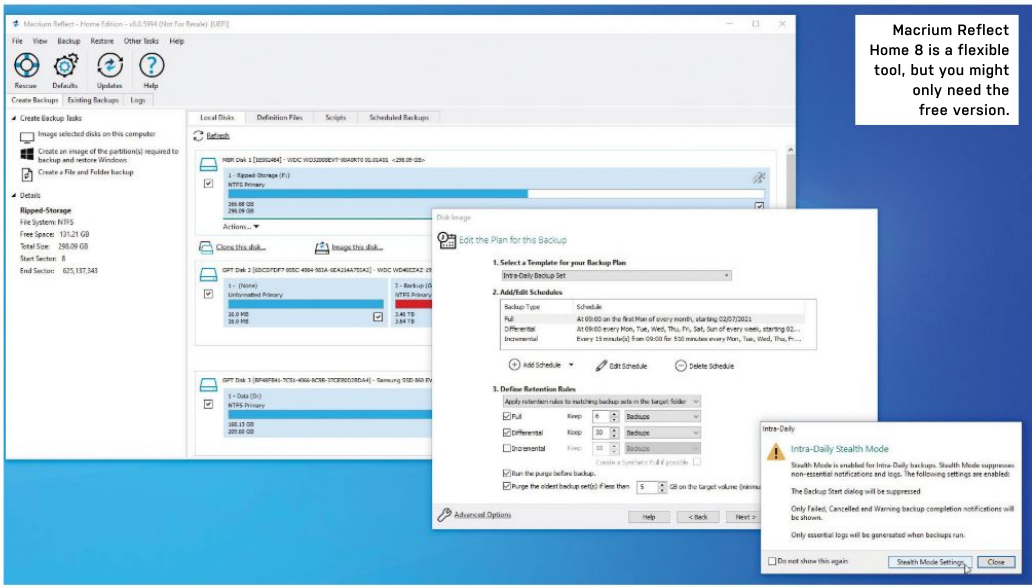

Macrium Reflect Home 8 is a flexible tool, but you might only need the free version.

combined size 350GB. In some ways, raw performance isn't important, so long as the backup can complete in the background without affecting your PC usage. Macrium took around 40 minutes to back up both drives locally to a single 261GB file—a separate progress window provides all the detail you need, plus an option to adjust CPU priority to make it quicker or less intrusive while you get on with other tasks.

Acronis's progress indicator is less verbose, but it displays a breakdown of file types across your backup after completion, along with an easily accessible summary. This reveals it came in smaller at 218GB, taking 57 minutes. In its defense, Acronis sets its CPU priority to low by default, but you can't change this during the backup.

Neither tool had a noticeable effect on performance, which means you can happily get on with other things, making backup speed less important, doubly so given that subsequent differential and incremental backups are smaller and much quicker.

Restoring from backups is straightforward enough, and both apps offer rescue media creation tools that are WinPE-based, so easy to use in the event of disaster. You can also recover individual files by mounting your images as virtual drives in File Explorer. Acronis goes further: If you back up to the cloud, you can access your files through an online portal in your web browser or via a mobile app.

Both programs can also clone drives—perfect when migrating to a new SSD, for example—and both support converting images for use as virtual machines. However, while both support Hyper-V format, Macrium 8 gets the jump on Acronis by adding support for VirtualBox.

Despite this, Acronis strikes back by offering additional tools and perks to broaden its appeal. Additional options include archiving large files to the cloud, system cleanup, and encrypted storage. Its mobile apps also do more than simply provide access to the online dashboard—you can back up your phone to your cloud storage or to your PC via your home Wi-Fi.

In contrast, Macrium focuses on polishing its core offering: Version 8's headline new feature allows you to back up as often as every 15 minutes using its Intra-Daily Backups (Acronis supports hourly backups in similar fashion). There's no magic new tech at play—the feature uses incremental backups wrapped up in a new scheduled option with some context-sensitive options (such as suppressing notifications to avoid being plagued by 15-minute reminders) to transform Macrium into a reliable snapshot tool that renders System Restore redundant.

So, which drive-imaging tool should you choose? Both provide an excellent service backing up your system, so you might want to choose based on feature set. Here, Acronis wins hands down, but all is not quite what it seems. Cloud backups are nice in theory, but imaging to the cloud is slow and ponderous. Another black mark against it is the need to pay an annual subscription for even just the basic product.

Macrium lacks those bonus features, but offers a solid, reliable—and versatile—way to back up all or part of your PC, plus you get a lifetime license for your money. The free version has served us well for years, but the additional features present in the Home edition—in particular support for incremental backups—make this an irresistible choice. –NICK PEERS

VERDICT 8 **Acronis TrueImage 2021**

GUARDIAN ANGEL Wide range of backup options; lots of extra tools; cloud options.

TINKERBELL Cloud backup slow; no standalone purchase option.

RECOMMENDED SPECS Intel Pentium G/AMD FX or better; 2GB RAM; AMD Radeon HD 7700 or better; Windows 7/10

$49.99/year for one device, http://acronis.com

VERDICT 9 **Macrium Reflect Home 8**

SHIELD OF STEEL Solid, reliable, and fast; no-nonsense user interface; flexible backup options.

CARDBOARD SHIELD Free version may be all you need.

RECOMMENDED SPECS 1GB RAM; Windows XP SP3 or later

$69.95 for 1 PC, http://macrium.com

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LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Maximum PDF Archive
> Router Reliability
> Data Scientist 2.0

Magazine Back Catalog

Zak, Back before you were born, *Maximum PC* offered the "PDF Archive" as an alternative to maintaining a physical library. While I realize that a digital subscription is offered (and I am a subscriber to it, plus the print version), there's no way to really "save" a copy other than take screenshots (ugh). I don't know how much revenue is generated from sales of past issues, so perhaps Future could make older issues available? For example, maybe issues older than a year or two could be posted somewhere.

Keep up the good work!

–B. Brabson

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Hey there! Firstly: rude. I'm not that young, ha-ha! Secondly, I absolutely 100-percent agree with you, we definitely need a PDF archive (again), and it's something I've been working quietly behind the scenes with *Linux Format* to sort of come up with a solution for. If you don't already know, *Maximum PC* falls under the Tech Specialist division at Future, so the *MPC* and *LXF* teams are quite close to one another; we have meetings together every day, and we often share gear and ideas with each other. Recently, the *Linux Format* team redeveloped its website and began hosting its own back catalog of PDFs online under a new system/server. In fact, you can see it in action here: www.linuxformat.com/archives. Basically, it allows subscribers to log in and view all of the back issues as PDFs without worry, simply using their subscription number and surname.

Linux Format was a sort of test dummy for the system, and the team suggested expanding it out across the company. I've offered to throw money at them to just get us hooked up to their server with our back catalog as well, but it's gone a touch quiet since then (this all happened around January time).

What I have done, though, is forward this email on to my boss (Graham Barlow), and the editor of *Linux Format* as well, as a way of re-instigating that debate, and hopefully with a little more pestering from me, we'll be able to see something more tangible in the following months. I'll keep you all updated, of course, but if you could, please do email zak.storey@futurenet.com asking for the archives to return. That way, I can keep slinging your emails on to Graham as proof that we want the archives back, and that it would be a worthwhile investment. Yes, I am that annoying to have as an employee.

As an aside, you're right, Future does see revenue from the sale of back issues; however, to my knowledge, the number of back issues available is usually quite limited. Typically, within three to four months of the issue being off sale, those back issues are out of stock, too. So, I don't see that being a problem, especially if you're a subscriber anyway. And, after all, we're *Maximum PC*—you should be able to read *Maximum PC* on a PC!

Router Reviews

Hi, Zak. We've chatted a few times over the years; congrats on becoming editor-in-chief!

One thing I would like to see is a review of routers that included their software reliability. I've abandoned Asus and Linksys because their software is extremely unstable. **–B. Finkelstein**

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Yeah, I've wanted to do router reviews for a while actually. It's always been a bit difficult, and sort of a taboo product to review in the magazine. More often than not, we feature them and other network-related technology as part of "Centerfold" or "Editor's Pick," because they're a nightmare to review from a logistical standpoint.

Because Internet infrastructure varies massively across the US, as do housing materials (which in turn can block Wi-Fi signals), reviewing routers and providing any form of quantitative benchmarks is challenging, to say the least.

We did cover one Netgear router a few issues back, but that was more of an objective qualitative look at the UI and features of the device, rather than a flat-out review with benchmarks. However, it might be something worth revisiting. Even attaching a NAS device isn't that helpful, because maximum throughput is

↘ submit your questions to: editor@maximumpc.com

often limited to the Ethernet ports of the NAS itself.

What I'll do is pencil in a few reviews for the next couple of issues, to act as those qualitative reviews, looking at the UI and how it functions on a day-by-day basis (heck, I think we all know I've been struggling with my Asus AX88U). Then I'll have a talk with the team and some of our more learned freelance writers, and find a solution to providing suitable benchmarks to add into the reviews after that. That's actually a similar idea to what we have planned for case reviews, too.

Data Scientist Rig '21?

Hey, I just had a crazy thought. Considering the Data Scientist rig originally appeared in your October 2020 issue, perhaps you could revisit that build in your October 2021 issue, except with the Asus board and any other updates that would seem appropriate, given new technological developments.

I'm sure there would be a sizeable subset of your readership who would find that interesting. And maybe this time you could give a spec list for both a high-end build and an intermediate system. I mean, maybe the high-end build would be around $5,000, and the medium-budget build might be half that.

I know that when I finally set out to do my build, I'll be trying to stay below $2,500, so having the specs for a build around that price point would be very helpful. Anyhow, I'm just thinking out loud here, and no hard feelings if you don't pursue this, but I thought it would be worth my time to throw the idea out there either way.

Thanks again, mate!

–Vincent Thompson

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: I do love that idea. We've been trying to get an RTX 3090 out of someone for months now—unsurprisingly, it's been an absolute nightmare. But this is definitely something I think we should revisit.

As you know, we did have considerable problems when it came to memory in the 2020 Data Scientist rig, and it was troublesome trying to get the full 128GB working with Threadripper, to say the least.

We are actually expecting AMD to launch new chips in the coming months—hopefully there will be a Threadripper 5000 series, just to bring everything in line once again, and maybe get even more cores into the madness that is that processor. I think the bigger question, though, is just how viable TR is as a platform now, especially with Ryzen being as potent as it is. I mean, the 5950X, for example, features 16 cores and 32 threads, with support for up to 128GB of DDR4 at some ridiculous speeds. Outside of the memory bandwidth itself, and given the no-doubt larger expenses bundled in with the TR platform, does it make sense to go with TR over a standard Ryzen build?

This is definitely something to consider, though. I've actually been brushing up on astrophysics and quantum mechanics lately myself. I know, I know—two wildly different fields and really random things to be interested in during your spare time, but it's engrossing stuff, and I find how they use computing to simulate data, particularly with astrophysics, fascinating, so it's one I'm keen to take a second look at. For science!

It might not make the October issue—I really want to wait for those new parts—but I'll be sure to schedule it in before the end of the year, including some more expansive benchmarks this time around, based on data analysis and such.

Bit of a digression here, but I've actually been talking to our production team and my esteemed art editor about introducing a fifth plate into the cover run of a future issue, either for Dream Machine or the 200th issue of *Maximum PC* (this is currently issue 194, not that the bigwigs like me telling you that, for whatever reason). A fifth plate enables us to do funky stuff with metallic colors on the cover. It costs a bit extra, but it should be an awesome edition of the mag.

Connection Standards

Hi all, I was quite sad to read that small segment on PCIe 5.0 and DDR5 in the last issue of *Maximum PC*. Especially when it was on the cover. Are there any plans to report on it in full? Thanks.

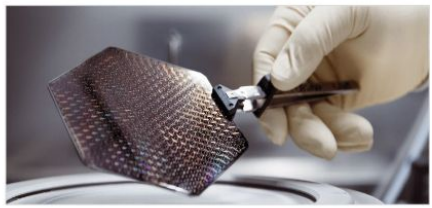
–Toby Kirkwood

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Hi, Toby. Sorry about that. We wanted to cover it in more depth at the time, but had to make some last-minute page cuts—annoying, I know. Nonetheless, I've commissioned Christian to write up a full analysis of all of the new connection standards going forward for next issue.

His feature will cover PCIe 5.0, DDR5, any new SSD form factors, Thunderbolt, USB—you name it, he's going to cover it. We'll be giving it the full eight-page treatment, so plenty of space to go into detail about the individual specs, when we expect it to come out, and whether it's going to be the revolutionary change we're all expecting.

[NOW ONLINE]

QUANTUM COMPUTING ON A CHIP: BRACE FOR THE REVOLUTION



In a moment of triumph that's being hailed as equivalent to the move from room-scale silicon technology down to desk-sized machines, quantum computing has now gone chip-scale—down from the room-scale contraptions you might have seen elsewhere, including in science fiction.

The development has been spearheaded by the UK's Cambridge-based quantum specialist Riverlane and its work with New York and London-based digital quantum company SeeQC. They're the first to deploy a quantum computing chip that has an integrated OS for workflow and qubit management (qubits are comparable to classical computing's transistors, but capable of pairing between themselves, instantly sharing information via quantum states, and also capable of representing both a 0 and a 1). The last time we achieved this level of miniaturization on a computing technology, we started the computing revolution. Now, expectations for a quantum revolution are on the table, and the world will have to adapt to the new reality. Read the full story at https://bit.ly/QuantumToms

© SEEQC

THE BUILDS

THIS MONTH'S STREET PRICES...

WE'D LIKE TO SAY it's time to upgrade our AMD budget build's processor, but stock availability is still hamstringing our efforts. Since we don't need the integrated graphics offered by the Athlon 3000G, we contemplated upgrading to a Ryzen 3 3100, doubling our core and thread counts. But this chip is still largely out of stock, and with no 5000-series budget Ryzen 3 CPU on the horizon, we're left with the dual-core 3000G. It's a bit cheaper this month, at least.

The AMD machine does get a few fun new additions, though. We've got a new motherboard, the MSI Pro B450M Pro-M2 (we don't know why it has "Pro" in the name twice either), and a new SSD, the Falcon NVMe drive from Adata. It promises upward of 3000MB/s read speeds in a PCIe 3.0 system, and comes at an excellent price for a quarter-terabyte of M.2 storage.

Our Intel build saw prices dropping across the board, with the Core i3-10100 falling to a very reasonable $142 and the Gigabyte B460M mobo dropping by 10 bucks, too. Both GPUs we recommend for the two budget systems have seen mild drops in street price, no doubt aided by crackdowns on cryptocurrency farming, but they're still far above what you should pay. Second-hand GPUs are still flooding sites like eBay, but be careful; cards that have previously been used for crypto mining may suffer from reduced longevity.

The Intel build gets two new components: memory and SSD. The memory is a swap back to Team Group's Vulcan Z RAM at 3,000MT/s, a reliable and affordable 2x 8GB kit that we can always recommend to builders on a budget. The SSD is a slightly more interesting tale....

Last issue, we opted for XPG's Gammix S5 M.2 drive, a supposedly gaming-oriented SSD with 256GB of storage. This was a mistake; the Gammix S11 is superior, offering 3D NAND flash memory rather than the S5's older, slower 3D TLC components. Despite only a price difference of five dollars, the S11 has hugely faster read times, with a maximum read speed of 3.5GB/s in a fully compatible system.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	500W EVGA BA 80+ Bronze	$40	
Mobo	MSI Pro B450 Pro-M2 MAX NEW	$70	
CPU	AMD Athlon 3000G	$90	
GPU	AMD Radeon RX 6700 XT 12GB NO STOCK	$480	$800
RAM	16GB (2x 8GB) GeIL Orion @ 3,000MHz	$80	
SSD	256GB Adata Falcon M.2 NVMe NEW	$45	
HDD	1TB WD Blue 1TB 7200	$45	
OS	Windows 10 Home 64-bit OEM	$32	
Approximate Price:		**$997 or $1,297**	

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	500W ARESGAME AVG500 80+ Bronze	$35	
Mobo	Gigabyte B460M DS3H V2	$87	
CPU	Intel Core i3-10100	$142	
GPU	Nvidia GeForce RTX 3060 12GB NO STOCK	$330	$700
RAM	16GB (2x 8GB) Team T-Force Vulcan Z @ 3,000MHz NEW	$75	
SSD	256GB XPG Gammix S11 M.2 PCIe 3.0 SSD NEW	$45	
HDD	1TB WD Blue 1TB 7200	$45	
OS	Windows 10 Home 64-bit OEM	$32	
Approximate Price:		**$886 or $1,256**	

THERE WAS PRECIOUS LITTLE to change in our mid-range PCs, so we've made some small shuffles here and there based on current pricings. Most of these components remain the best-value parts of their kind (the Enermax and Cooler Master AIOs in particular), but we were able to make a few changes. The most significant alteration is the AMD system's new motherboard, an X570-Plus mobo from Asus's TUF Gaming range. With an M.2 heat shield, PCIe 4.0 support, and a slick black-and-yellow color scheme, it's a solid choice of board for a mid-range custom PC, capable of supporting 3000- or 5000-series Ryzen processors. Note that a BIOS update may be required for 5000-series chips; this is especially likely if you're buying your motherboard second-hand.

The AMD system also gets new memory, another lateral shift to G.Skill's dependable Ripjaws V RAM. As usual, the change is to keep abreast of memory pricing, which is constantly moving. When picking memory, work out the speed and capacity you want, then narrow it down to the best-value kit from trusted named brands.

Our mid-range Intel build gets a slightly updated PSU, the EVGA SuperNOVA 650 G5. You can look out for EVGA's G6 series now, but the G5 models are still great PSUs and currently more affordable. The Intel rig also returns to Corsair's excellent Force MP600 PCIe 4.0 SSD, thanks to a sale that brought the price down.

With CPUs still in high demand (as we were writing this, an article popped up about a smuggler arrested in Hong Kong for attempting to conceal 256 Intel chips on his legs), we considered swapping out the Core i7-11700K for its 11700F counterpart, which is currently more readily available and about 60 dollars cheaper. We ended up leaving the 11700K in place, due to its slightly better performance and overclocking capabilities. The 11700F lacks integrated graphics and has its multipliers locked against manual overclocking, but if those aren't issues for you, we still recommend it.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	650W Fractal Design Ion Gold	$90	
Mobo	Asus AM4 TUF Gaming X570-Plus NEW	$180	
CPU	AMD Ryzen 5 5600X	$290	
Cooler	240mm Cooler Master Masterliquid ML240L RGB	$70	
GPU	Nvidia GeForce RTX 3070 8GB NO STOCK	$500	$1,065
RAM	16GB (2x 8GB) G.Skill Ripjaws V Series @ 3,600MHz NEW	$85	
SSD	500GB PNY XLR8 CS3040 M.2 PCIe 4.0 NEW	$100	
HDD	1TB WD Blue 1TB 7200	$45	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,542 or $2,107

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	650W EVGA SuperNOVA 650 G5 NEW	$82	
Mobo	ASRock Z590M PRO4	$187	
CPU	Intel Core i7-11700K	$390	
Cooler	Enermax Liqmax III 240 RGB	$70	
GPU	AMD Radeon RX 6800 XT 16GB NO STOCK	$650	$1,300
RAM	16GB (2x 8GB) Silicon Power XPOWER Turbine @ 3,600MHz	$85	
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0 NEW	$100	
HDD	1TB WD Blue 1TB 7200	$45	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,791 or $2,441

GPU PRICES KEEP FALLING, even if they're still a far cry from their RRPs. We still don't recommend paying through the nose for one of these high-end cards right now, but at least street prices aren't sitting above double the original value. If you really want a new GPU, your best bet is to track restocks via social media updates and camp out reseller websites. High-end CPU prices are stable(ish) at the time of writing, but expect delays if ordering online.

While we're sticking with the same chips, both our turbo builds boast shiny new motherboards. The AMD build gets the MSI MPG X570 Gaming Edge Wi-Fi, while the Intel machine gets the ASRock Z590 Steel Legend Wi-Fi. Both have PCIe 4.0 capabilities and Wi-Fi support, and we love the clean silver aesthetic of the Steel Legend.

Both machines get new SSDs, too, as the new generation of ultrafast 3D NAND drives make the previous round of PCIe 4.0 SSDs look slow as heck. The AMD system has a Samsung 980 Pro, while the Intel build gets Gigabyte's shiny new Aorus 7000s drive. Both are 1TB drives, offering maximum read speeds of a staggering 7,000MB/s and write speeds of up to 5,000MB/s (5,500 in the case of the Gigabyte drive). These SSDs are a bit more expensive than their regular PCIe 4.0 counterparts, but their performance is nigh-unparalleled—without shelling out for an insane new Optane SSD.

A new power supply also felt appropriate for the AMD machine, given some pricing shifts, and we opted for NZXT's excellent C750 model, with 80+ Gold efficiency certification. We like NZXT's PSUs; they're clean little units in matte black, and the C750's modular design means we won't have any excess cables to worry about.

Finally, we sprung for a new AIO. Yes, there might be more affordable ones, but we couldn't resist Lian Li's awesome Galahad 360 cooler. The sleek white model is a high-end AIO with flashy RGB lighting and machined aluminum components, such as additional heat shielding on the radiator. The pump block head with the Lian Li logo is magnetic, and can be rotated or replaced with a simpler aluminum plate that accentuates the lighting around the edges.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150	
PSU	750W NZXT C750 80+ Gold **NEW**	$105	
Mobo	MSI MPG X570 Gaming Edge Wi-Fi **NEW**	$211	
CPU	AMD Ryzen 7 5800X	$410	
Cooler	Lian Li Galahad RGB AIO 360mm White **NEW**	$145	
GPU	Nvidia GeForce RTX 3080 10GB **NO STOCK**	$700	$1,750
RAM	32GB (2x 16GB) Patriot Viper Steel DDR4 @ 3,600MHz	$155	
SSD	1TB Samsung 980 Pro M.2 PCIe 4.0 **NEW**	$230	
HDD	6TB Western Digital Blue	$150	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $2,288 or $3,338

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150	
PSU	750W EVGA SuperNOVA 750 G5	$100	
Mobo	ASRock Z590 Steel Legend Wi-Fi **NEW**	$220	
CPU	Intel Core i9-11900K	$550	
Cooler	MSI MAG CoreLiquid 360R AIO	$130	
GPU	AMD Radeon RX 6900 XT 16GB **NO STOCK**	$999	$1,475
RAM	32GB (2x 16GB) G.Skill TridentZ RGB @ 3,600MHz	$180	
SSD	1TB Gigabyte Aorus Gen4 7000s M.2 PCIe 4.0 **NEW**	$210	
HDD	6TB Western Digital Blue	$150	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $2,721 or $3,197

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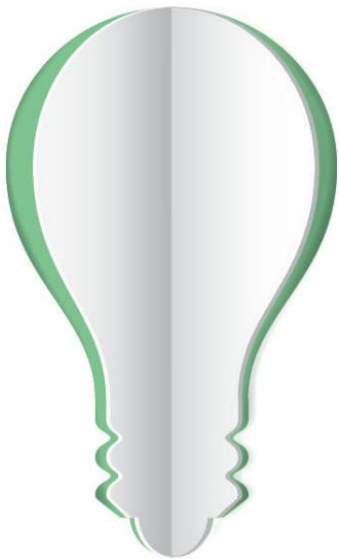

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